EHSS

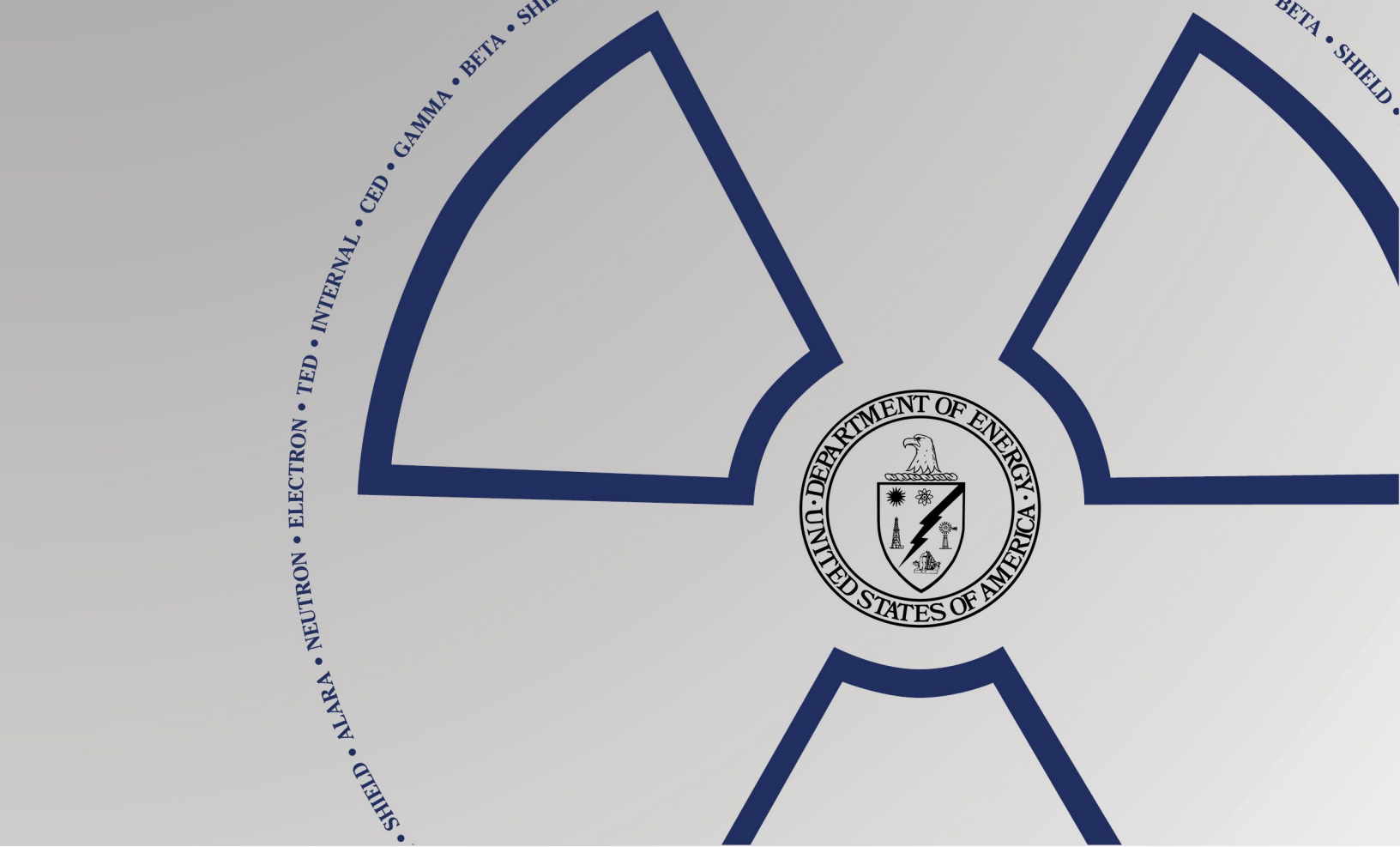
Office of Environment, Health, Safety and Security

# DOE 2017 Occupational Radiation Exposure

1993 - 2018

25th Anniversary

## December 2018



This document is available on the
U.S. Department of Energy
Radiation Exposure Monitoring System Program Web Site at:
http://energy.gov/ehss/occupational-radiation-exposure


# DOE 2017 Occupational Radiation Exposure

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# Foreword



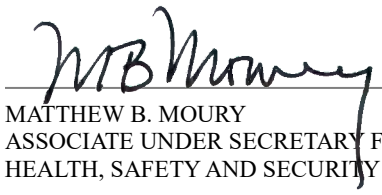
The U. S. Department of Energy (DOE) *2017 Occupational Radiation Exposure Report* presents the results of analyses of occupational radiation exposures monitoring at DOE facilities during 2017. This report includes occupational radiation exposure information for all DOE employees, contractors, and subcontractors, as well as members of the public in controlled areas that are monitored for exposure to radiation.

The Radiation Exposure Monitoring System (REMS) program is a key component of the Office of the Associate Under Secretary for Environment, Health, Safety and Security (AU). AU informs management and stakeholders of the continued vigilance and success of DOE sites in minimizing radiation exposure to workers and the public.

DOE has the responsibility to protect the health and safety of DOE employees, contractors, and subcontractors. AU provides the corporate-level leadership to establish clear expectations for health, safety, environment, and security programs. The Office of Environment, Safety and Health (ES&H) Reporting and Analysis collects, analyzes, and disseminates data and performance indicators, such as occupational radiation exposure information, to support DOE's mission.

DOE remains focused on maintaining radiation exposures below the administrative control levels (ACLs) and the DOE radiation dose limits, and to further reducing exposure through the as low as reasonably achievable (ALARA) principle. The *DOE 2017 Occupational Radiation Exposure Report* provides an evaluation of DOE-wide performance regarding compliance with Title 10, *Code of Federal Regulations* (CFR), Part 835, Occupational Radiation Protection dose limits and an overview of the status of radiation exposures of the DOE workforce. In addition, this report serves as a risk management tool for radiological safety programs and provides useful information to DOE organizations, epidemiologists, and researchers.

As part of DOE's continual improvement process, we will appreciate your response to the User Survey included at the end of this report.



MATTHEW B. MOURY
ASSOCIATE UNDER SECRETARY FOR ENVIRONMENT,
HEALTH, SAFETY AND SECURITY

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## LIST OF EXHIBITS

## LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ACL | Administrative Control Level |
| AEC | U.S. Atomic Energy Commission |
| ALARA | As Low As Reasonably Achievable |
| AMWTP | Advanced Mixed Waste Treatment Project |
| ANL | Argonne National Laboratory |
| ATR | Advanced Test Reactor |
| AU | Office of the Associate Under Secretary for Environment, Health, Safety and Security |
| AU-23 | Office of ES&H Reporting and Analysis |
| BNL | Brookhaven National Laboratory |
| CEBAF | Continuous Electron Beam Accelerator Facility |
| CED | Committed Effective Dose |
| CEDE | Committed Effective Dose Equivalent |
| CEqD | Committed Equivalent Dose |
| CFR | Code of Federal Regulations |
| D&D | Decontamination and Decommissioning |
| DOE | U.S. Department of Energy |
| ED | Effective Dose |
| EE | Office of Energy Efficiency and Renewable Energy |
| EM | Office of Environmental Management |
| EPA | U.S. Environmental Protection Agency |
| EqD | Equivalent Dose |
| ERDA | Energy Research and Development Administration |
| ES&H | Environment, Safety, & Health |
| ETEC | Energy Technology Engineering Center |
| ETTP | East Tennessee Technology Park (Formerly K-25 Site) |
| F-18 | Flourine-18 |
| Fermilab | Fermi National Accelerator Laboratory |
| ICP | Idaho Cleanup Project |
| ICRP | International Commission on Radiological Protection |
| INL | Idaho National Laboratory |
| KC-NSC | Kansas City National Security Campus |
| LANL | Los Alamos National Laboratory |
| LBNL | Lawrence Berkeley National Laboratory |
| LINAC | Linear Accelerator |
| LLNL | Lawrence Livermore National Laboratory |
| LM | Office of Legacy Management |
| mSv | Millisievert |
| NE | Office of Nuclear Energy, Science and Technology |
| NNSA | National Nuclear Security Administration |
| NNSS | Nevada National Security Site, formally known as Nevada Test Site (NTS) |
| NRC | U.S. Nuclear Regulatory Commission |

| | |
|---|---|
| NREL | National Renewable Energy Laboratory |
| NYSERDA | New York State Energy Research and Development Authority |
| | |
| OR | Oak Ridge |
| ORISE | Oak Ridge Institute for Science and Education |
| ORNL | Oak Ridge National Laboratory |
| ORP | Office of River Protection |
| OST | Office of Secure Transportation |
| | |
| PA | Protective Agreement for Exchange of Information |
| PFP | Plutonium Finishing Plant |
| PGDP | Paducah Gaseous Diffusion Plant |
| PNNL | Pacific Northwest National Laboratory |
| PORTS | Portsmouth Gaseous Diffusion Plant |
| PPPL | Princeton Plasma Physics Laboratory |
| | |
| rem | Roentgen equivalent man |
| REMS | Radiation Exposure Monitoring System |
| | |
| SC | Office of Science |
| SLAC | SLAC National Accelerator Laboratory |
| SNM | Special Nuclear Material |
| SNL | Sandia National Laboratories |
| SPRU | Separations Process Research Unit |
| SPEAR3 | Stanford Positron-Electron Asymmetric Ring |
| SRS | Savannah River Site |
| Sv | Sievert |
| | |
| TED | Total Effective Dose |
| TEqD | Total Equivalent Dose |
| TJNAF | Thomas Jefferson National Accelerator Facility |
| TRU | Transuranic |
| TSS | Transportation Safeguards System |
| | |
| U | Uranium |
| U-234 | Uranium-234 |
| UMTRA | Uranium Mill Tailings Remedial Action Project |
| USEC | United States Enrichment Corporation |
| | |
| WIPP | Waste Isolation Pilot Plant |
| WTP | Waste Treatment Plant |
| WVDP | West Valley Demonstration Project |
| | |
| Y-12 | Y-12 National Security Complex |

# Executive Summary

The U. S. Department of Energy (DOE) Office of Environment, Safety, and Health (ES&H) Reporting and Analysis within the Office of the Associate Under Secretary for Environment, Health, Safety, and Security (AU) publishes the annual *DOE Occupational Radiation Exposure Report* to provide an overview of the status of radiation protection practices at DOE (including the National Nuclear Security Administration [NNSA]). The *DOE 2017 Occupational Radiation Exposure Report* provides an evaluation of DOE-wide performance regarding compliance with Title 10, *Code of Federal Regulations*, Part 835, Occupational Radiation Protection (10 CFR 835) dose limits and as low as reasonably achievable (ALARA) process requirements for the calendar year 2017. In addition, the report provides data to DOE organizations responsible for developing policies for protection of individuals from the adverse health effects of radiation. The report also provides a summary and an analysis of occupational radiation exposure data from the monitoring of individuals involved in DOE activities. An analysis of individual dose data includes an examination of:

- Doses exceeding the 5 rem (50 millisievert [mSv]) DOE regulatory limit; and
- Doses exceeding the 2 rem (20 mSv) DOE administrative control level (ACL).

The term "dose" as used in this report refers to the Total Effective Dose (TED) and is measured in units of "rem" (Roentgen equivalent man). The TED is the summation of the effective dose from sources of radiation that are external and internal to the body. The term "collective dose" is the sum of the individual doses received by a group of individuals and is shown in units of "person-rem." The total DOE collective TED increased by 7 percent from 2016 to 2017 (as shown in *Exhibit ES-1)* due to increased activities at key DOE sites.

Another primary indicator of the level of radiation exposure is the average measurable dose, which normalizes the collective dose over the population of workers who received a measurable dose. The average measurable TED decreased by less than 1 percent from 2016 to 2017, as shown in *Exhibit ES-2*.

***Exhibit ES-1:***
***Collective TED (person-rem), 2013–2017.***

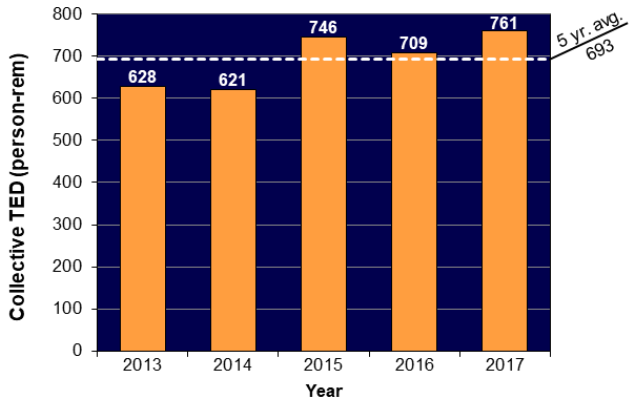
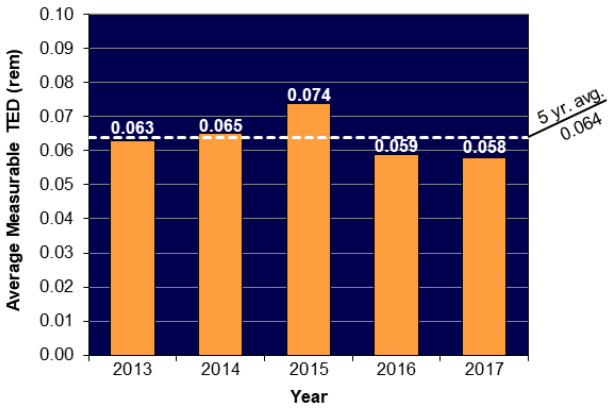



***Exhibit ES-2:***
***Average Measurable TED (rem), 2013–2017.***



## NOTABLE FINDINGS

- No doses exceeded the DOE occupational dose limit of 5 rem (50 mSv) TED or the DOE ACL of 2 rem (20 mSv) TED in 2017.

- The collective TED increased 7 percent from 709 person-rem (7,090 person-mSv) in 2016 to 761 person-rem (7,610 person-mSv) in 2017.

- The sites contributing the majority of the collective TED were (in descending order): Savannah River Site (SRS), Oak Ridge (OR), Los Alamos National Laboratory (LANL), Idaho, and Hanford. These sites accounted for 84 percent of the collective TED in 2017. The collective TED increased at LANL, SRS, and OR. The increase at LANL was due largely to increased work activities at TA-55 plutonium facility operations which were fully resumed following the 2013 shutdown. The increase at SRS can be attributed to workers engaging in work with a high potential for exposure, and at Oak Ridge, the increase in collective TED was attributed to increased project work activities at hot cell and radiochemistry facilities, and maintenance and waste handling activities at neutron research and radiochemistry facilities. The collective TED decreased at Hanford and Idaho. The decrease at Hanford was due to a change in work activities at the plutonium finishing plant facility (PFP). The collective TED at Idaho decreased for a variety of reasons including decreased experiment handling and shipping operations; and the installation of new engineering controls related to waste treatment efforts.

- The collective CED (Committed Effective Dose from sources internal to the body) increased by 7 percent from 61.5 person-rem (615 person-mSv) in 2016 to 66.0 person-rem (660 person-mSv) in 2017, mainly as a result of an increase in internal dose at Y-12 National Security Complex (Y-12). Uranium-234 (U-234) accounted for the largest percentage of the collective CED, with over 99 percent of this dose accrued at Y-12.

- The collective TED for transient workers (individuals monitored at more than one DOE site) decreased by 15 percent from 23.5 person-rem (235 person-mSv) in 2016 to 20.0 person-rem (200 person-mSv) in 2017.

Over the past 5 years, all monitored individuals received doses below the 2 rem (20 mSv) TED ACL, which is well below the DOE annual limit of 5 rem (50 mSv) TED. The occupational radiation exposure records show that in 2017, DOE facilities continued to comply with DOE dose limits and ACLs and worked to minimize exposure to individuals.

To access this report and other information on occupational radiation exposure at DOE, visit the DOE AU web site at:

**https://energy.gov/ehss/occupational-radiation-exposure**

# Introduction



The Department of Energy *(DOE) 2017 Occupational Radiation Exposure Report* presents the results of analyses of occupational radiation exposures at DOE facilities during 2017. This report includes occupational radiation exposure information for all DOE employees, contractors, and subcontractors, as well as members of the public in controlled areas that are monitored for exposure to radiation. The 100 DOE organizations submitting radiation exposure reports for 2017 have been grouped into 34 sites. This information has been analyzed and trended to provide a measure of DOE's performance in protecting its workers from radiation.

## 1.1 Report Organization

This report is organized into the five sections listed below. A User Survey form is included at the end of this report and users are encouraged to provide feedback. Additional supporting technical information on occupational radiation exposure, such as tables of data, report appendices, and additional items are available on the DOE web site at: https://energy.gov/ehss/occupational-radiation-exposure.

## 1.2 Report Availability

This report is available online and can be downloaded from:

**https://www.energy.gov/ehss/listings/annual-doe-occupational-radiation-exposure-reports**

Requests for access to the data files, or for individual dose records used to compile this report, as well as suggestions and comments, should be directed to:

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Visit the DOE Radiation Exposure Monitoring System (REMS) web site for more information on occupational radiation exposure, such as the following:

- Annual occupational radiation exposure reports in pdf since 1974;
- Guidance on reporting radiation exposure information to the DOE REMS;
- Updated REMS-Online Query Tool;
- Guidance on how to request a dose history for an individual;
- Statistical data since 1987 for analysis;
- Applicable DOE orders and manuals for the recordkeeping and reporting of occupational radiation exposure at DOE;
- Occupational Exposure Dashboard—interactive data explorer;
- Ten Year Summary—graphical comprehensive overview of past 10 years of radiation exposure data; and
- As low as reasonably achievable (ALARA) activities at DOE.

## 1.3 25th Anniversary Report


On November 4, 1968, the U.S. Atomic Energy Commission (AEC) began requiring the reporting of an annual statistical summary of occupational radiation exposure information to a central repository at AEC Headquarters. At that time, there were only four categories of AEC facilities required to report. These facilities were considered to have the greatest potential for significant occupational doses. The reports included the total number of individuals who were monitored per dose range and a cumulative radiation exposure report for individuals who terminated employment during the year.

In January 1975, with the split of AEC into the Energy Research and Development Administration (ERDA) and the U.S. Nuclear Regulatory Commission (NRC), each agency assumed responsibility for collecting and maintaining occupational radiation exposure information reported by the facilities under its jurisdiction. A further federal reorganization in 1977 replaced ERDA with the DOE.

Each agency established Privacy Act Systems of Records for occupational exposure information. AU manages REMS for DOE and is listed in the Federal Register as DOE-35. The NRC Radiation Exposure Information and Reporting System is managed by the NRC's Radiation Protection Branch within the Office of Nuclear Regulatory Research and is listed in the Federal Register as NRC-27. Both Systems of Records document the approved routine uses of the records, which specifically includes providing federal agencies with the records for monitoring and/or evaluating an individual's radiation exposure.

REMS serves as the central repository of occupational radiation exposure records for all DOE employees, contractors, and subcontractors, as well as members of the public in controlled areas that are monitored for exposure to radiation. The database consists of individual occupational radiation exposure records for DOE monitored workers from 1987 to the present.

Prior to 1987, DOE only required the reporting of statistical summaries and termination reports. The 10 CFR 835, requires sites to monitor individual occupational radiation exposure for DOE employees, contractors, and subcontractors, as well as members of the public. The DOE Order 231.1B Admin Chg. 1, Environment, Safety and Health Reporting (Approved 6/27/2011), requires the occupational radiation exposure data to be reported to REMS repository.

In 1994-1996, an Inter-agency Agreement was established between DOE and NRC to develop a new DOE database system that would: benefit from the innovative application of lessons learned from related experiences by NRC; share and transfer technology used by NRC to support DOE programs including the operation and maintenance of REMS database; and assist in development of a new DOE annual report of occupational radiation exposure. Since 1998, DOE and NRC have an ongoing Protective Agreement for Exchange of Information (PA) to comply with the prior dose requirements of regulations in both agencies. These requests often pertain to worker exposures at both NRC and DOE facilities. The PA facilitates timely responses to these requests. For this reason the databases of both agencies are managed by the Oak Ridge Institute for Science and Education (ORISE) in Oak Ridge, TN.

While the databases are separate and independent, the following are examples of the benefits of the interagency cooperation:

- Security protocols required to handle both paper and electronic records containing Privacy Act information
- Software application development and data management efficiencies
- The ability for monitored workers to request DOE and NRC exposure records through one consolidated request form
- Data entry, quality assurance/quality control processes, records storage and disposition efficiency
- Data extraction, analysis, and report production commonalities
- Joint participation in approved epidemiologic research projects.

Several notable improvements to REMS have been achieved since this cooperative effort began:

- In 1995, the DOE data was migrated from a Cobol text-based system into a relational database system that allowed for much faster data extraction and more detailed analysis.
- The DOE annual report was completely redesigned and a 3-year report was compiled and published containing the 1992-1994 data which brought the annual report series up to date. The DOE 2017 Occupational Radiation Exposure report marks the 25th year of publication in the current format.
- Increasing cyber security requirements lead to the development of a secure web portal for the submittal of annual radiation exposure records from the DOE sites. The successful implementation of this feature allowed DOE

and NRC to continue collecting data during and after the Anthrax attacks in 2001 when federal agencies began irradiating mail which prevented sites from sending in exposure records on diskettes and compact disks (CDs).

- In 2006, in a response to concerns about the potential loss of Privacy Act data sent through the mail, DOE issued a policy stating that the only acceptable method for submitting radiation exposure records to REMS is through the secure data submittal web page.
- A software application called REMSView was developed to allow the DOE sites to verify the content and format of the electronic exposure records prior to submittal to REMS.
- A web-based "REMS Query Tool" was developed to allow users to examine exposure information across the DOE complex by selecting aggregated data for specific years by site, Program Office, facility type, and other categories of interest. The results can be viewed on screen, or downloaded to Excel for further analysis and presentation.
- "E-products" were developed and placed on the REMS web site to allow for a dashboard view, or a historical perspective on radiation exposure and protection at DOE.

In addition to the changes and improvements in the information systems, there have also been changes in the standards and regulations for both agencies. A complete list of regulatory changes over the past 50 years would be extensive and beyond the scope of this report, however, the primary objective of reducing occupational radiation exposures through vigilant regulatory oversight, analysis, and informed policy-making has remained unchanged. A summary of the current requirement for DOE is presented in Section 2 of this report, along with a discussion of the most recent amendments to 10 CFR 835.

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# Standards and Requirements



One of DOE's primary objectives is to provide a safe and healthy workplace for all DOE employees, contractors, and subcontractors, as well as members of the public. To meet this objective, AU establishes comprehensive and integrated programs for the protection of workers from hazards in the workplace, including ionizing radiation. The basic DOE standards for occupational radiation protection include radiation dose limits that establish maximum permissible doses to workers. In addition, contractors and subcontractors are required to maintain exposures as far below the limits as is reasonable through application of the ALARA process which incorporates pre-job planning, engineering controls, and worker training.

This section discusses DOE's radiation protection standards and requirements for 2017. For more information on past requirements, visit the DOE web site for DOE Directives, Delegations, and Requirements at https://www.directives.doe.gov/. See the Archives section under the Directives menu for historical references.

## 2.1 Radiation Protection Requirements

DOE radiation protection standards are based on Federal guidance for protection against occupational radiation exposure promulgated by the U.S. Environmental Protection Agency (EPA) in 1987 [1]. This guidance, initially implemented by DOE in 1989, was based on the 1977 recommendations of the International Commission on Radiological Protection (ICRP) Publication 26 [2] and the 1987 recommendations of the National Council on Radiation Protection and Measurements Publication 91 [3]. The EPA guidance recommends that internal dose be added to the external whole-body dose to determine the TED equivalent. The laws and requirements for occupational radiation protection pertaining to the information collected and presented in this report are summarized in *Exhibit 2-1*.

## 2.2 Radiation Dose Limits

Radiation dose limits are codified in 10 CFR 835.202, 206, 207, and 208 [4] and are summarized in *Exhibit 2-2*.

## 2.3 Reporting Requirements

On June 27, 2011, DOE Order (O) 231.1A was updated and reissued as DOE O 231.1B, *Environment, Safety and Health Reporting* [5], which contains the requirements for reporting annual individual radiation exposure records to the REMS repository. At this time, DOE Manual 231.1-1A, *Environment, Safety and Health Reporting Manual*, was cancelled. Specific instructions for preparing occupational exposure data for submittal to the REMS repository are contained in the REMS Reporting Guide available online at:

https://www.energy.gov/ehss/downloads/radiation-exposure-monitoring-systems-data-reporting-guide [6].

***Exhibit 2-1:***
***Laws and Requirements Pertaining to the Collection and Reporting of Radiation Exposures.***

| Title | Date | Description |
|---|---|---|
| 10 CFR 835, *Occupational Radiation Protection* [4] | Issued 12/14/93<br>Amended 11/4/98<br>Amended 6/8/07<br>Amended 4/13/11<br>Amended 8/11/17 | Establishes radiation protection standards, limits, and program requirements for protecting individuals from ionizing radiation that results from the conduct of DOE activities. |
| DOE Order 231.1B, *Environment, Safety and Health Reporting* [5] | Approved 6/27/11 | Requires the annual reporting of occupational radiation exposure records to the DOE REMS repository. |
| REMS Reporting Guide [6] | Issued 2/23/12 | Specifies the current format and content of the reports required by DOE Order 231.1B. |

***Exhibit 2-2:***
***DOE Dose Limits from 10 CFR 835.***

| Personnel Category | Section of 10 CFR 835 | Type of Exposure | Acronym | Annual Limit |
|---|---|---|---|---|
| General employees | 835.202 | Total effective dose. The sum of the effective dose (for external exposures) and the committed effective dose. | TED | 5 rem |
| | | The sum of the equivalent dose to the whole body for external exposures and the committed equivalent dose to any organ or tissue other than the skin or the lens of the eye. | EqD-WB + CEqD (TOD) | 50 rem |
| | | Equivalent Dose to the Lens of the Eye | EqD-Eye | 15 rem |
| | | The sum of the equivalent dose to the skin or to any extremity for external exposures and the committed equivalent dose to the skin or to any extremity | EqD-SkWB + CEqD-SK<br>and<br>EqD to the maximally exposed extremity + CEqD-SK | 50 rem |
| Declared pregnant workers* | 835.206 | The equivalent dose to the embryo/fetus from the period of conception to birth as a result of occupational exposure of a declared pregnant worker. | EqD-Fetus | 0.500 rem from the period of conception to birth |
| Minors | 835.207 | Total effective dose | TED | 0.100 rem |
| Members of the public in a controlled area | 835.208 | Total effective dose | TED | 0.100 rem |

* Limit applies to the embryo/fetus.

## 2.4 Amendments to 10 CFR 835

In August 2006, DOE published a proposed amendment to 10 CFR 835 in the *Federal Register*, and in June 2007, the amended rule was published. The amendment:

- Specified new dosimetric terminology and quantities based on ICRP 60/68 in place of ICRP 26/30;
- Specified ICRP 60 *tissue weighting factors* in place of ICRP 26 *weighting factors*;
- Specified ICRP 60 *radiation weighting factors* in place of ICRP 26 *quality factors*;
- Amended other parts of the regulation that changed as a result of adopting ICRP 60 dosimetry system;
- Used the ICRP 68 dose conversion factors to determine values for the derived air concentrations; and
- Adopted other changes intended to enhance radiation protection.

The amended rule became effective on July 9, 2007, and was required to be fully implemented by DOE sites by July 9, 2010. Because all sites began complying with the new requirements during 2010, all terminology used in this annual report reflects that of the amendment. In addition, 10 CFR 835 was revised in April 2011 when Appendix C (Derived Air Concentration for Workers) was updated. On 8/11/2017, Appendices C and E were amended. The amendment to Appendix C corrected the air immersion DAC for any single radionuclide not listed in the Appendix C table with a decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than two hours, adjusted for an 8-hr work day. The amendment to Appendix E corrected the activity information of two radionuclides, Rh-102 and Rh-102m.

# Occupational Radiation Dose at DOE



## 3.1 Analysis of the Data

Key indicators are analyzed to identify and correlate parameters that impact occupational radiation exposure doses at DOE.

The key indicators for analyzing aggregate data are:

- number of records for monitored individuals;
- individuals with measurable dose;
- collective dose;
- average measurable dose; and
- dose distribution.

The analysis of key indicators for individual dose data includes:

- doses exceeding the 5 rem (50 millisievert [mSv]) DOE regulatory limit; and
- doses exceeding the 2 rem (20 mSv) DOE administrative control level (ACL).

Additional information is provided in this report concerning activities at sites contributing to the majority of the collective dose. The data for prior years contained in this report are subject to change because sites may submit corrections for previous years.

## 3.2 Analysis of Aggregate Data

### 3.2.1 Number of Monitored Individuals

As stated in Section 2, DOE requires the reporting of the results of annual individual occupational radiation exposure monitoring to the REMS repository. The results are reported by each facility in the form of a record for a monitoring period for each individual. An individual may have been monitored more than once at the same facility (e.g., multiple short-term assignments) or may have been monitored at more than one facility during the year. These result in more than one record for an individual during the year in the REMS repository. However, the impact of multiple records per person on the annual trends and aggregate analysis of the data in this report is not significant since it occurs consistently from year to year. An analysis of the number of individuals who are monitored at more than one location during the year is provided in Section 3.5 which supports this assertion. The term "number of monitored individuals" will be used herein with the understanding that it is determined by the count of records for monitored individuals.

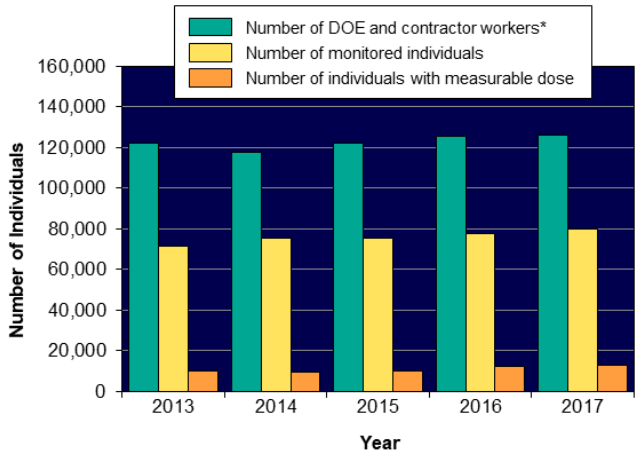
### 3.2.2 Number of Individuals with Measurable Dose

DOE uses the number of individuals with measurable dose to represent the exposed workforce size. In this context, "with measurable dose" means that a detectable value was reported for the individual.

Over the past 5-year period, measurable doses to all monitored individuals were below a TED of 2 rem (20 mSv) TED, the DOE ACL, and hence well below the DOE regulatory limit of 5 rem (50 mSv) TED in a year.

*Exhibit 3-1a* and *Exhibit 3-1b* show the number of DOE and contractor workers, the total number of individuals monitored for radiation dose, the number of individuals with a measurable dose, and the relative percentages of individuals with measurable dose for the past 5 years. The number of DOE and contract workers was calculated by converting the total number of hours worked each year into an estimate of the number of workers by dividing the total hours worked by the average number of work hours per year. It is therefore, not a true count of individuals, but is a representation of the total size of the DOE workforce and is included here in order to compare it to the number of workers who are monitored.

***Exhibit 3-1a:***
***Monitoring of the DOE Workforce, 2013–2017.***




* The number of DOE and contractor workers was determined from the total annual work hours at DOE [7] converted to full-time equivalents.

**For 2017, 63% of the DOE workforce was monitored for radiation dose, and 16% of monitored individuals received a measurable dose.**

***Exhibit 3-2b:***
***Monitoring of the DOE Workforce, 2013–2017.***

| Year | DOE & Contractor Workforce | Number of Monitored Individuals | Percent of Monitored Individuals* | Number of Individuals with Measurable Dose | Percent of Individuals with Measurable Dose* |
|---|---|---|---|---|---|
| 2013 | 122,101 | 71,599 | 59% ▼ | 9,906 | 14% ▲ |
| 2014 | 117,704 | 75,470 | 64% ▲ | 9,508 | 13% ▼ |
| 2015 | 122,141 | 75,587 | 62% ▼ | 10,033 | 13% |
| 2016 | 125,322 | 77,836 | 62% | 11,988 | 15% ▲ |
| 2017 | 126,214 | 79,888 | 63% ▲ | 13,025 | 16% ▲ |
| **5-Year Average** | **122,801** | **76,693** | **62%** | **10,892** | **14%** |

* Up arrows indicate an increase from the previous year's value. Down arrows indicate a decrease from the previous year's value.

### 3.2.3 Collective Dose

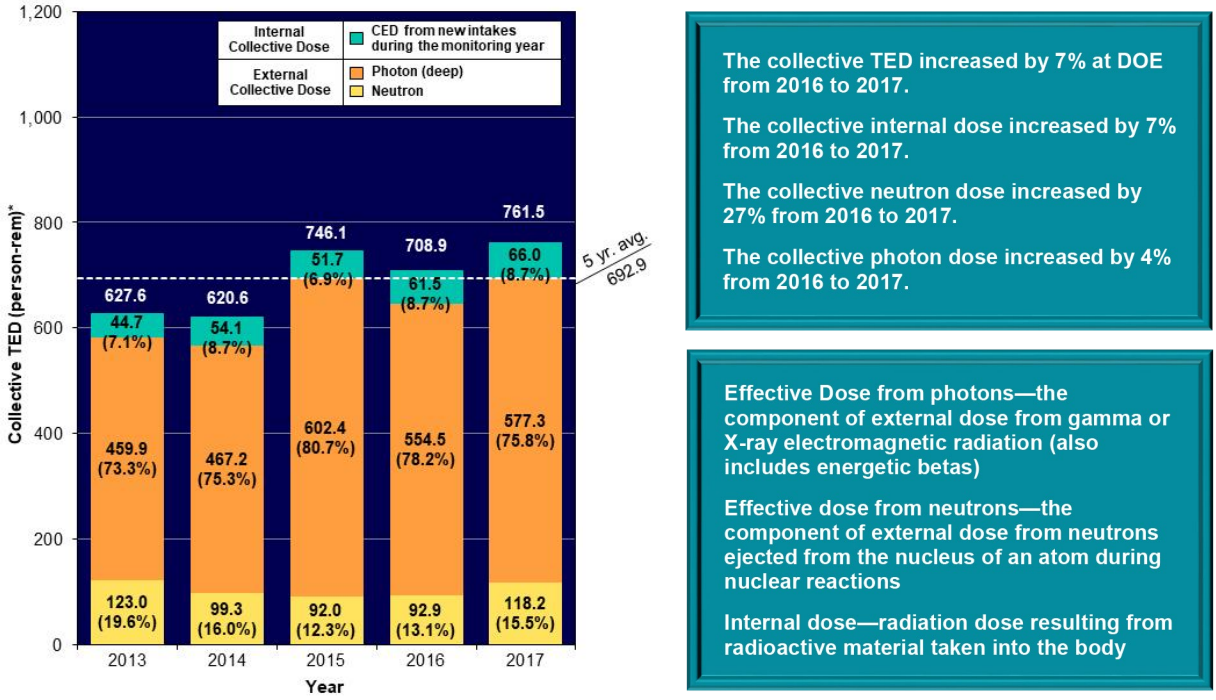
The collective dose is the sum of the dose received by all individuals with a measurable dose and is measured in units of person-rem and person-mSv. DOE monitors the collective dose as one measure of the overall performance of radiation protection programs to keep individual exposures and collective exposures ALARA.

In this report, the term "collective dose" is also applied to various types of radiation dose, such as external or internal, and will be specified in conjunction with the term "collective" to clarify the intended meaning.

As shown in *Exhibit 3-2*, the collective TED increased at DOE by 7 percent from 708.9 person-rem (7,089 person-mSv) in 2016 to 761.5 person-rem (7,615 person-mSv) in 2017.

The internal dose is based on the 50-year CED methodology. Under this methodology, the cumulative dose received from the intake of radioactive material over the next 50 years is assigned to the individual as a one-time dose in the year of intake. In other words, the CED is the effective dose from radionuclides taken into the body during the reporting year integrated over the next 50 years.

***Exhibit 3-3:***
***Components of TED, 2013–2017.***




* The percentages in parentheses represent the percentage of each dose component to the collective TED.

The internal dose component of the collective TED increased by 7 percent from 61.5 person-rem (615 person-mSv) in 2016 to 66.0 person-rem (660 person-mSv) in 2017, due to increases in internal doses across the DOE complex including Y-12. The collective photon dose increased by 4 percent from 554.5 person-rem (5,545 person-mSv) in 2016 to 577.3 person-rem (5,773 person-mSv) in 2017.

The neutron component of the collective TED increased by 27 percent from 92.9 person-rem (929 person-mSv) in 2016 to 118.2 person-rem (1,182 person-mSv) in 2017. The increase resulted primarily from increases in collective neutron dose at Oak Ridge National Laboratory (ORNL) (101.5 percent), and LANL (42 percent).

The five sites that contributed most (84 percent) of the DOE collective TED in 2017 were (in descending order of collective TED): SRS—27 percent; Oak Ridge—26 percent (including East Tennessee Technology Park [ETTP], Y-12, ORNL, and ORISE); LANL—25 percent; Idaho Site—12 percent (including Advanced Mixed Waste Treatment Project [AMWTP], Idaho Cleanup Project [ICP], and Idaho National Laboratory [INL]); and Hanford—10 percent (including the Hanford Site, Pacific Northwest National Laboratory [PNNL], and Office of River Protection [ORP]).

LANL, SRS, and Oak Ridge had increases in collective TED in 2017 compared with 2016 (68 percent, 55 percent and 15 percent, respectively). The other two top contributors reported decreases in collective TED. In descending order of the percent decrease in collective TED are Hanford (28 percent lower) and Idaho (15 percent lower). (See section 3.4.3.)

### 3.2.4 Average Measurable Dose

The average measurable dose to DOE workers, a key radiation dose indicator, is calculated by dividing the collective dose (in this case, TED) by the number of individuals with measurable dose for TED. This is the average most commonly used in this and other reports when examining trends and comparing doses received by workers, because it reflects the exclusion of those individuals receiving a less than measurable dose.

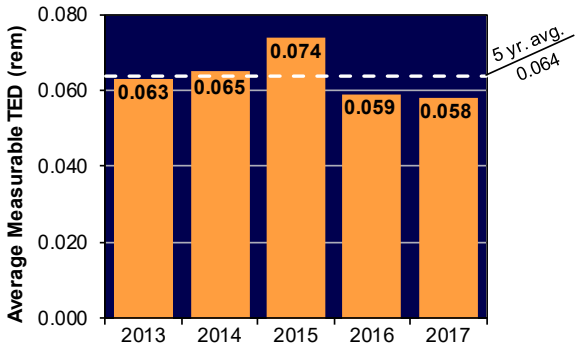
The average measurable TED is shown in *Exhibit 3-3*. The average measurable TED decreased by less than 1 percent from 0.059 rem (0.590 mSv) in 2016 to 0.058 rem (0.580 mSv) in 2017. While the collective dose and average measurable dose serve as measures of the magnitude of the dose accrued by DOE workers, they do not depict the distribution of doses among the worker population.

### 3.2.5 Dose Distribution

Exposure data are commonly analyzed in terms of dose intervals to depict the TED distribution among the worker population. *Exhibit 3-4* shows the number of individuals in each of 11 different dose ranges. The number of individuals receiving doses above 0.100 rem (1 mSv) is included to show the number of individuals with doses above the monitoring threshold specified in 10 CFR 835.402(a) and (c) [4].

*Exhibit 3-4* shows that the dose (TED) distribution for 2017 was higher in the less than measurable and measurable to 0.100 ranges compared with the 2016 data. Ninety-nine percent of all individuals monitored had doses less than 0.250 rem (2.5 mSv).

***Exhibit 3-4:***
***Average Measurable TED, 2013–2017.***




Of those individuals with measurable dose, *Exhibit 3-5* presents the dose distribution in terms of the percentage of individuals with measurable TED in each range. Eighty-five percent of monitored individuals received doses below the required monitoring threshold of 0.100 rem (1 mSv) specified in 10 CFR 835.402 (a) and (c).

This reflects DOE's conservative practice of monitoring more individuals than are required in order to ensure adequate protection of the worker and that ALARA principles are being effectively implemented at reducing radiation exposure.

**Eighty-five percent of monitored individuals received doses below the required monitoring threshold of 0.100 rem (1 mSv) specified in 10 CFR 835.402 (a) and (c).**

***Exhibit 3-5:***
***Distribution of TED by Dose Range, 2013–2017.***

| | TED Range (rem) | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|
| Number of Individuals in Each Dose Range* | Less than measurable | 61,693 | 65,962 | 65,554 | 65,848 | 66,863 |
| | Measurable to 0.100 | 8,154 | 7,712 | 8,029 | 10,143 | 11,011 |
| | 0.100–0.250 | 1,245 | 1,259 | 1,342 | 1,246 | 1,396 |
| | 0.250–0.500 | 422 | 444 | 449 | 451 | 481 |
| | 0.500–0.750 | 48 | 72 | 123 | 90 | 103 |
| | 0.750–1.000 | 28 | 15 | 49 | 38 | 13 |
| | 1.0–2.0 | 9 | 6 | 41 | 20 | 21 |
| | 2.0–3.0 | | | | | |
| | 3.0–4.0 | | | | | |
| | 4.0–5.0 | | | | | |
| | >5.0 | | | | | |
| Total number of records for monitored individuals | | 71,599 | 75,470 | 75,587 | 77,836 | 79,888 |
| Number with measurable dose | | 9,906 | 9,508 | 10,033 | 11,988 | 13,025 |
| Number with dose >0.100 rem | | 1,752 | 1,796 | 2,004 | 1,845 | 2,014 |
| Collective TED (person-rem) | | 627.632 | 620.621 | 746.088 | 708.921 | 761.474 |
| Average measurable TED (rem) | | 0.063 | 0.065 | 0.074 | 0.059 | 0.058 |

* Individuals with doses equal to the dose value separating the dose ranges are included in the next higher dose range.

***Exhibit 3-6:***
***Percentage of Individuals with Measurable TED by Dose Range, 2013–2017.***

| | TED Range (rem) | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|
| Percentage of Individuals with Measurable TED* | Measurable <0.100 | 82.31% | 81.11% | 80.03% | 84.61% | 84.54% |
| | 0.100–0.250 | 12.57% | 13.24% | 13.38% | 10.39% | 10.72% |
| | 0.250–0.500 | 4.26% | 4.67% | 4.48% | 3.76% | 3.69% |
| | 0.500–0.750 | 0.48% | 0.76% | 1.23% | 0.75% | 0.79% |
| | 0.750–1.000 | 0.28% | 0.16% | 0.49% | 0.32% | 0.10% |
| | 1.0–2.0 | 0.09% | 0.06% | 0.41% | 0.17% | 0.16% |
| | 2.0–3.0 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| | >3.0 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| % of monitored individuals with measurable dose | | 14% | 13% | 13% | 15% | 16% |
| % of monitored individuals with dose > 0.100 rem | | 2% | 2% | 3% | 2% | 3% |

* Individuals with doses equal to the dose value separating the dose ranges are included in the next higher dose range.

## 3.3 Analysis of Individual Dose Data

The previous analysis is based on aggregate data for DOE. From an individual worker perspective and a regulatory perspective, it is important to examine the doses received by individuals in the elevated dose ranges to understand the circumstances leading to these doses in the workplace and to better manage, or where practical, avoid these doses in the future.

### 3.3.1 Doses in Excess of DOE Limit

No individual exceeded the TED regulatory limit (5 rem [50 mSv]) from 2013 through 2017.

### 3.3.2 Doses in Excess of Administrative Control Level

The DOE Standard Radiological Control (DOE-STD-1098-2017) [7] establishes a 2 rem (20 mSv) ACL for TED per year per person for all DOE activities. Approval by the appropriate Secretarial Officer or designee should be required prior to allowing an individual to exceed this value. The Standard states that each DOE site should establish an annual facility ACL based on historical and projected exposures and that no individual should be allowed to exceed this value without prior facility management approval.

No individual exceeded 2 rem (20 mSv) TED from 2013 through 2017.

### 3.3.3 Intakes of Radioactive Material

DOE tracks the number of intakes as a performance measure in the report. DOE emphasizes the importance of taking measures to avoid intakes and maintain doses as low as reasonable through the ALARA principle.

*Exhibit 3-6* shows the number of individuals with measurable CED, collective CED, and average measurable CED for 2013 to 2017. The number of individuals with measurable CED increased by 3 percent from 1,241 in 2016 to 1,282 in 2017, while the collective CED increased by 7 percent. The average measurable CED increased from 0.050 rem (0.500 mSv) in 2016 to 0.051 rem (0.510 mSv) in 2017 and remained slightly above the 5-year average measurable CED.

Ninety-nine percent of the collective CED in 2017 was from uranium intakes at Y-12 during the operation and management of Enriched Uranium Operations facilities at the site. Compared with external dose, few workers at DOE receive measurable internal dose. Larger fluctuations may occur from year to year in the number of workers and the collective CED compared to other components of TED.

*Exhibit 3-7* shows the distribution of the CED from 2013 to 2017. The total number of individuals with measurable CED in each dose range is the sum of the number of individuals receiving a CED in the dose range. Individuals may have had more than one intake of radioactive material, but the site would report one CED value from these intakes. Doses below 0.020 rem (0.200 mSv) are shown as a separate dose range, to show the large number of individuals in this low dose range.

***Exhibit 3-7:***
***Number of Individuals with Measurable CED, Collective CED, and Average Measurable CED, 2013–2017.***

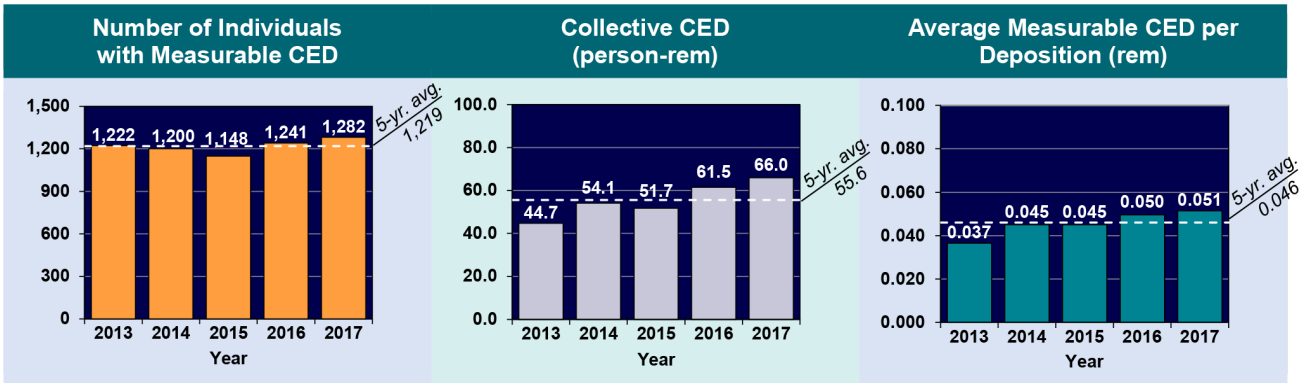



***Exhibit 3-8:***
***Internal Dose Distribution from Intakes, 2013–2017.***

| Year | Number of Individuals with CED in the Ranges (rem)* | | | | | | | | | | | Total No. of Indiv. | Total Collective CED (person-rem) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Meas. <0.020 | 0.020–0.100 | 0.100–0.250 | 0.250–0.500 | 0.500–0.750 | 0.750–1.000 | 1.0–2.0 | 2.0–3.0 | 3.0–4.0 | 4.0–5.0 | >5.0 | | |
| 2013 | 668 | 439 | 107 | 5 | 2 | 1 | | | | | | 1,222 | 44.687 |
| 2014 | 565 | 479 | 140 | 14 | 2 | | | | | | | 1,200 | 54.082 |
| 2015 | 540 | 467 | 117 | 23 | 1 | | | | | | | 1,148 | 51.714 |
| 2016 | 546 | 522 | 135 | 36 | 2 | | | | | | | 1,241 | 61.544 |
| 2017 | 548 | 543 | 149 | 39 | 3 | | | | | | | 1,282 | 65.989 |

* Individuals with doses equal to the dose value separating the dose ranges are included in the next higher dose range.

The internal dose records indicate that the majority of the intakes resulted in very low doses. In 2017, 43 percent of the internal dose records were for doses below 0.020 rem (0.200 mSv). Over the 5-year period, internal doses accounted for 8 percent of the collective TED; although only 13 percent of the individuals who received internal doses had estimated doses above the monitoring threshold (0.100 rem [1 mSv]) specified in 10 CFR 835.402(c) [4]. It is noted that the CED is a dose received over a 50 year period after the intake that is all credited to the worker in the year of intake so the actual annual dose is lower.

### 3.3.4 Bioassay and Intake Summary Information

For the monitoring year 2017, bioassay and intake summary information was required to be reported under the REMS Reporting Guide [6]. During the past 5 years, "Urinalysis" has been reported as the most common method of bioassay measurement used to determine internal doses to the individuals. *Exhibit 3-8* shows the breakdown of bioassay measurements by measurement type and number of measurements. The Pacific Northwest National Laboratory had the largest percentage increase (12 percent) in the number of "Urinalysis" measurements in 2017. The measurements reported as "In Vivo" include direct measurements of the radioactive material in the body of the monitored person. Examples of "In Vivo" measurements include whole body counts and lung or thyroid counts. Two sites, SRS and Hanford, accounted for 53 percent of the "In Vivo" measurements.

*Exhibit 3-9* shows the reported "Air Sampling" measurements which are used to calculate the amount of airborne radioactive material taken into the body and the resultant internal dose. The numbers shown are based on the number of measurements taken and not the number of individuals monitored. Individuals may have measurements taken more than once during the year. The majority of the measurements reported as "Air Sampling" accounted for 22 percent of the total measurements. Waste Isolation Pilot Plant had the largest percentage increase in the number of "Air Sampling" measurements, increasing from 8 air samples in 2016, to 88 air samples in 2017 (see *Exhibit 3-14* for additional information).

***Exhibit 3-9:***
***Bioassay Measurements, 2013–2017.***

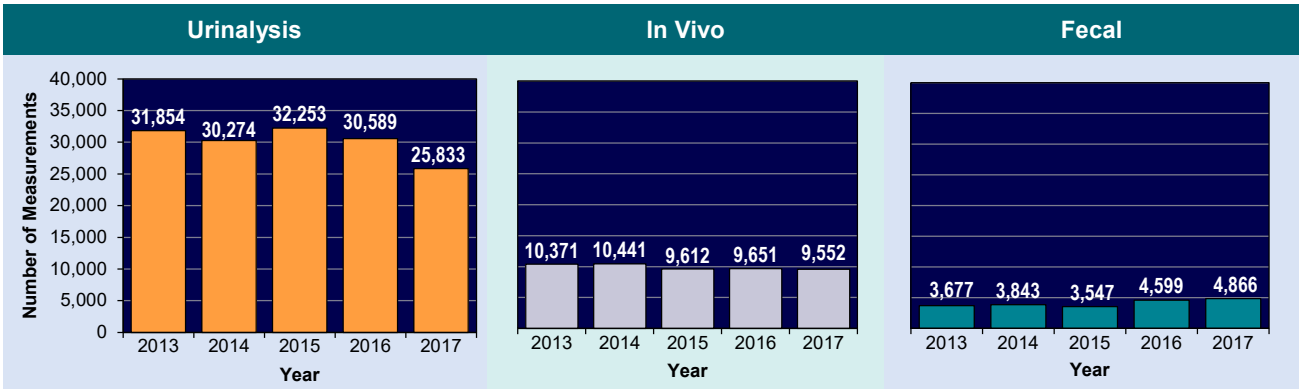
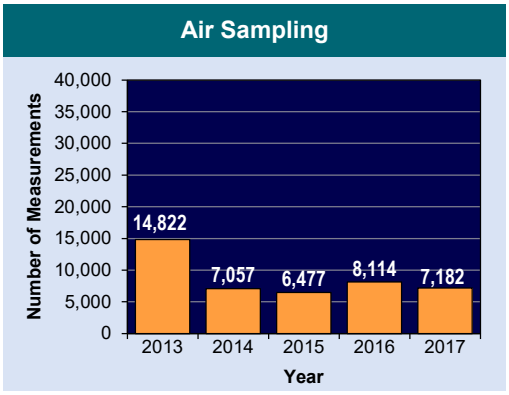



***Exhibit 3-10:***
***Air Sampling Measurements, 2013-2017.***

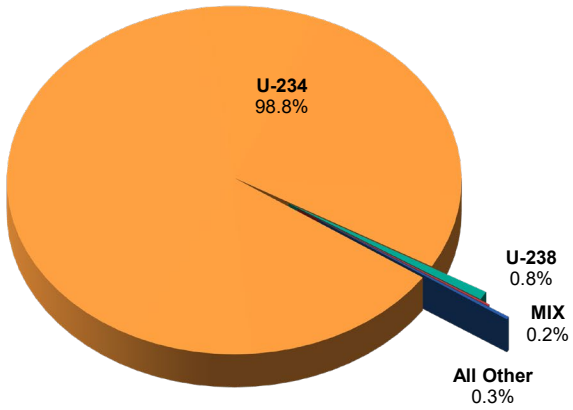



Sixty-six percent of the "Urinalysis" measurements in 2017 were performed at four sites: Y-12, SRS, Paducah Gaseous Diffusion Plant (PGDP), and Lawrence Livermore National Laboratory (LLNL).

Y-12 performed the largest number of bioassay and air sampling measurements combined, comprising 36 percent of the total measurements taken.

*Exhibit 3-10* shows the breakdown of the collective CED by radionuclide for 2017. U-234 accounted for the largest percentage of the collective CED, with over 99 percent of this dose accrued at Y-12.

***Exhibit 3-11:***
***Collective CED by Radionuclide from Internal Exposure, 2017.***




The annual REMS appendices can be found at https://www.energy.gov/ehss/listings/annual-doe-occupational-radiation-exposure-reports, within each annual report. *Exhibits B-4*, Internal Dose by Site; *B-18*, Internal Dose by Facility Type and Nuclide; *B-20*, Internal Dose by Labor Category; and *B-22*, Internal Dose Distribution by Site and Nuclide offer more detailed information regarding intake data.

## 3.4 Analysis of Site Data

### 3.4.1 Collective TED by Site and Other Facilities

The collective TED values for 2015 through 2017 for the major DOE sites and operations/field offices are shown graphically in *Exhibit 3-11*. A list of the collective TED and number of individuals with measurable TED by DOE sites is shown in *Exhibit 3-12*.

***Exhibit 3-12:***
***Collective TED by DOE Site for 2015–2017.***

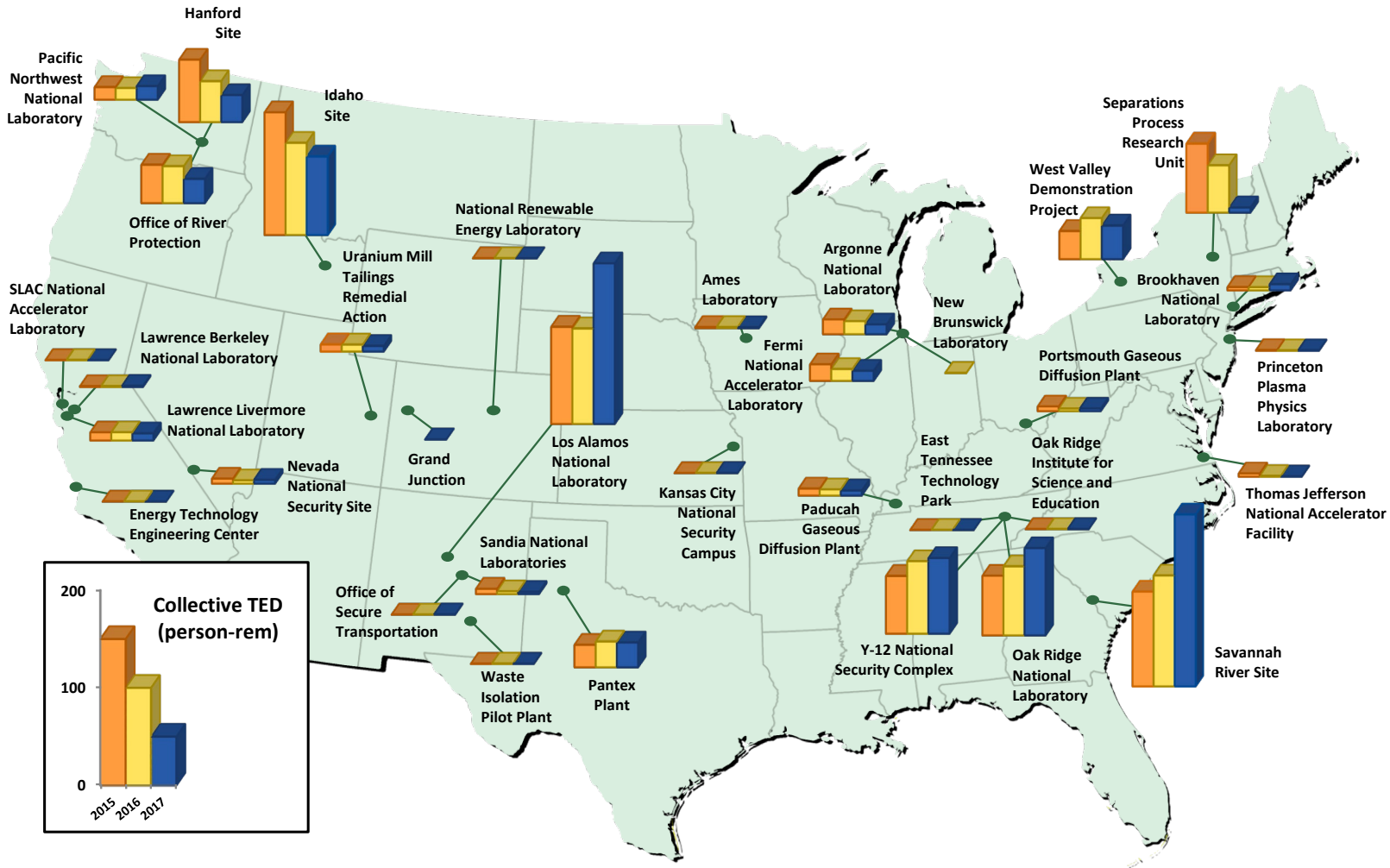


***Exhibit 3-13:***
***Collective TED and Number of Individuals with Measurable TED by DOE Site, 2015–2017.***

| Site | 2015 | | 2016 | | 2017 | |
|---|---|---|---|---|---|---|
| | Collective TED (person-rem) | Number with Meas. TED | Collective TED (person-rem) | Number with Meas. TED | Collective TED (person-rem) | Number with Meas. TED |
| Ames Laboratory | 1.247 | 39 | 1.240 | 41 | 1.053 | 38 |
| Argonne National Laboratory | 14.818 | 83 | 13.080 | 70 | 9.885 | 75 |
| Brookhaven National Laboratory | 3.345 | 134 | 3.217 | 84 | 6.087 | 78 |
| Energy Technology Engineering Center | 0.068 | 3 | 0.089 | 2 | 0.026 | 2 |
| Fermi National Accelerator Laboratory | 16.640 | 235 | 11.930 | 232 | 10.210 | 201 |
| Grand Junction Site * | - | - | - | - | 0.010 | 2 |
| Hanford: | | | | | | |
| Hanford Site | 62.612 | 687 | 41.095 | 1,217 | 27.003 | 717 |
| Office of River Protection | 38.608 | 648 | 37.102 | 929 | 24.387 | 597 |
| Pacific Northwest National Laboratory | 12.581 | 461 | 11.599 | 420 | 13.555 | 517 |
| *Hanford Totals:* | *113.801* | *1,796* | *89.796* | *2,566* | *64.945* | *1,831* |
| Idaho Site | **123.232** | 1,331 | 92.670 | 1,273 | 78.946 | 1,177 |
| Kansas City National Security Campus | 0.020 | 12 | 0.063 | 24 | 0.171 | 44 |
| Lawrence Berkeley National Laboratory | 0.796 | 11 | 0.823 | 13 | 1.257 | 18 |
| Lawrence Livermore National Laboratory | 8.123 | 112 | 8.215 | 98 | 7.134 | 115 |
| Los Alamos National Laboratory | 97.209 | 1,135 | 95.565 | 1,106 | 160.772 | 1,850 |
| National Renewable Energy Laboratory | 0.028 | 4 | 0.034 | 7 | 0.020 | 4 |
| Nevada National Security Site | 5.045 | 98 | 3.295 | 84 | 3.858 | 94 |
| New Brunswick Laboratory ** | 0.000 | 0 | 0.096 | 4 | - | - |
| Oak Ridge: | | | | | | |
| East Tennessee Technology Park | 0.059 | 4 | 0.114 | 3 | 0.093 | 6 |
| Oak Ridge Institute for Science and Education | 0.122 | 10 | 0.171 | 9 | 0.243 | 23 |
| Oak Ridge National Laboratory | 59.959 | 598 | 69.378 | 617 | 87.621 | 661 |
| Y-12 National Security Complex | 58.010 | 1,201 | 72.807 | 1,460 | 75.890 | 1,453 |
| *Oak Ridge Totals:* | *118.150* | *1,813* | **142.470** | *2,089* | *163.847* | *2,143* |
| Office of Secure Transportation | 0.029 | 2 | 0.072 | 3 | 0.311 | 8 |
| Paducah Gaseous Diffusion Plant | 7.058 | 337 | 6.201 | 559 | 5.159 | 113 |
| Pantex Plant | 22.618 | 301 | 25.918 | 295 | 24.986 | 333 |
| Portsmouth Gaseous Diffusion Plant | 4.716 | 59 | 2.509 | 40 | 2.553 | 41 |
| Princeton Plasma Physics Laboratory | 0.623 | 126 | 0.311 | 78 | 0.361 | 49 |
| Sandia National Laboratories | 5.284 | 99 | 2.756 | 68 | 2.146 | 73 |
| Savannah River Site | 95.074 | **1,884** | 111.338 | **2,799** | **172.546** | **4,411** |
| Separations Process Research Unit | 69.291 | 149 | 47.541 | 101 | 5.185 | 59 |
| SLAC National Accelerator Laboratory | 0.069 | 2 | 0.170 | 6 | 0.057 | 4 |
| Thomas Jefferson National Accelerator Facility | 3.348 | 47 | 0.777 | 30 | 0.270 | 20 |
| Uranium Mill Tailings Remedial Action Project | 7.177 | 86 | 7.044 | 131 | 5.656 | 66 |
| Waste Isolation Pilot Plant | 0.161 | 12 | 0.311 | 22 | 0.279 | 17 |
| West Valley Demonstration Project | 28.107 | 122 | 41.122 | 147 | 33.653 | 154 |
| Service Center Personnel *** | 0.011 | 1 | 0.268 | 16 | 0.091 | 5 |
| **Totals** | **746.088** | **10,033** | **708.921** | **11,988** | **761.474** | **13,025** |

Note: Bold and boxed values indicate the greatest value in each column.
* Grand Junction Site began reporting under the Office of Legacy Management in 2017.
** In May 2016, the Office of Science reorganized the New Brunswick Laboratory. Prior operations have ceased and the name is no longer used
*** Includes personnel at National Nuclear Security Administration (NNSA) Albuquerque complex, Oak Ridge, and WIPP in addition to several smaller facilities not associated with a DOE site.

The collective TED increased 7 percent from 709 person-rem (7,090 person-mSv) in 2016 to 761 person-rem (7,610 person-mSv) in 2017, with SRS; Oak Ridge (including ETTP, Y-12, ORNL, and ORISE); LANL; Idaho (including INL, ICP, and AMWTP); and Hanford (including the Hanford Site, PNNL, and ORP) contributing 84 percent of the total DOE collective TED.

### 3.4.2 Changes by Site from 2016 to 2017

*Exhibit 3-13* shows the collective TED, the number with a measurable TED, and the average measurable TED, as well as the percentage change in these values from the previous year. Some of the largest percentage changes occurred at relatively small facilities, where conditions may fluctuate from year to year due to changes in workload and tasks conducted.

Changes that have the most impact in the overall values at DOE typically occur at sites with large collective TED. In 2017, the largest percentage of change was observed at the Brookhaven National Laboratory, which increased by 89 percent from 2016. (See section 3.4.3.)

Fourteen of the 34 DOE sites reported increases in the collective TED from the 2016 values, and 20 of the 34 DOE sites reported decreases in the collective TED from the 2016 values.

Seventeen of the 34 reporting sites experienced increases in the number of workers with a measurable TED from 2016 to 2017. The largest increase in total number of workers with a measurable TED occurred at Savannah River Site (SRS) with an increase of 1,612 workers.

Sixteen of the 34 reporting sites experienced decreases in the number of workers with a measurable TED from 2016 to 2017. The largest decrease in the number of workers receiving a measurable TED occurred at Hanford Site with a decrease of 500 workers. One site (Energy Technology Engineering Center) experienced no change. A discussion of activities at the highest dose facilities is included in section 3.4.3.

### 3.4.3 Activities Significantly Contributing to Collective Dose in 2017

In an effort to identify the reasons for changes in the collective dose at DOE, all of the sites provided information on activities that significantly contributed to the collective dose for 2017 as required in the REMS Reporting Guide, Item 1. In *Exhibit 3-14*, these sites are presented in descending order of collective TED with a dotted line representing the site's five year average TED.

***Site Listing***

***Exhibit 3-14:***
***Site Dose Data, 2017.***

| Site | 2017 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Collective TED (person-rem) | Percent Change from 2016 | Number of Monitored | Percent Change from 2016 | Number with Meas. TED | Percent Change from 2016 | Avg. Meas. TED (person-rem) | Percent Change from 2016 |
| Ames Laboratory | 1.053 | -15% ▼ | 204 | 7% ▲ | 38 | -7% ▼ | 0.028 | -8% ▼ |
| Argonne National Laboratory | 9.885 | -24% ▼ | 1,779 | ◊ ▼ | 75 | 7% ▲ | 0.132 | -29% ▼ |
| Brookhaven National Laboratory | 6.087 | **89%** ▲ | 3,669 | **15%** ▲ | 78 | -7% ▼ | 0.078 | 104% ▲ |
| Energy Technology Engineering Center | 0.026 | ◊ ▼ | 5 | ◊ ▼ | 2 | ◊ - | 0.013 | ◊ ▼ |
| Fermi National Accelerator Laboratory | 10.210 | -14% ▼ | 1,370 | -1% ▼ | 201 | -13% ▼ | 0.051 | -1% ▼ |
| Grand Junction Site | 0.100 | ◊ ▲ | 22 | ◊ - | 2 | ◊ ▲ | 0.005 | ◊ ▲ |
| Hanford: | | | | | | | | |
| Hanford Site | 27.003 | -34% ▼ | 3,977 | -7% ▼ | 717 | -41% ▼ | 0.038 | 12% ▲ |
| Office of River Protection | 24.387 | -34% ▼ | 2,663 | ◊ ▼ | 597 | -36% ▼ | 0.041 | 2% ▲ |
| Pacific Northwest National Laboratory | 13.555 | 17% ▲ | 2,467 | ◊ ▼ | 517 | 23% ▲ | 0.026 | -5% ▼ |
| *Hanford Totals:* | *64.945* | *-28%* ▼ | *9,107* | *-3%* ▼ | *1,831* | *-29%* ▼ | *0.035* | *1%* ▲ |
| Idaho Site | 78.946 | -15% ▼ | 7,178 | 10% ▲ | 1,177 | -8% ▼ | 0.067 | -8% ▼ |
| Kansas City National Security Campus | 0.171 | ◊ ▲ | 114 | ◊ ▲ | 44 | ◊ ▲ | 0.004 | ◊ ▲ |
| Lawrence Berkeley National Laboratory | 1.257 | 53% ▲ | 941 | 2% ▲ | 18 | 38% ▲ | 0.070 | 10% ▲ |
| Lawrence Livermore National Laboratory | 7.134 | -13% ▼ | 8,657 | -1% ▼ | 115 | 17% ▲ | 0.062 | -26% ▼ |
| Los Alamos National Laboratory | 160.772 | 68% ▲ | **10,876** | 13% ▲ | 1,850 | **67%** ▲ | 0.087 | 1% ▼ |
| National Renewable Energy Laboratory | 0.020 | ◊ ▼ | 11 | ◊ ▼ | 4 | ◊ ▼ | 0.005 | ◊ ▲ |
| Nevada National Security Site | 3.858 | 17% ▲ | 1,536 | -5% ▼ | 94 | 12% ▲ | 0.041 | 5% ▲ |
| Oak Ridge: | | | | | | | | |
| East Tennessee Technology Park | 0.093 | ◊ ▼ | 372 | ◊ ▲ | 6 | ◊ ▲ | 0.016 | ◊ ▼ |
| Oak Ridge Institute for Science and Education | 0.243 | ◊ ▲ | 97 | ◊ ▼ | 23 | ◊ ▲ | 0.011 | ◊ ▼ |
| Oak Ridge National Laboratory | 87.621 | 26% ▲ | 4,209 | 3% ▲ | 661 | 7% ▲ | 0.133 | 18% ▲ |
| Y-12 National Security Complex | 75.890 | 4% ▲ | 6,158 | -3% ▼ | 1,453 | ◊ ▼ | 0.052 | 5% ▲ |
| *Oak Ridge Totals:* | *163.847* | *15%* ▲ | *10,836* | *-1%* ▼ | *2,143* | *3%* ▲ | *0.076* | *12%* ▲ |
| Office of Secure Transportation | 0.311 | ◊ ▲ | 305 | ◊ ▼ | 8 | ◊ ▲ | 0.039 | ◊ ▲ |
| Paducah Gaseous Diffusion Plant | 5.159 | -17% ▼ | 1,875 | -14% ▼ | 113 | -80% ▼ | 0.046 | **312%** ▲ |
| Pantex Plant | 24.986 | -4% ▼ | 4,655 | 1% ▲ | 333 | 13% ▲ | 0.075 | -15% ▼ |
| Portsmouth Gaseous Diffusion Plant | 2.553 | 2% ▲ | 2,602 | 2% ▲ | 41 | 3% ▲ | 0.062 | -1% ▼ |
| Princeton Plasma Physics Laboratory | 0.361 | ◊ ▲ | 374 | ◊ ▼ | 49 | ◊ ▼ | 0.007 | ◊ ▲ |
| Sandia National Laboratories | 2.146 | -22% ▼ | 1,784 | -4% ▼ | 73 | 7% ▲ | 0.029 | -27% ▼ |
| Savannah River Site | **172.546** | 55% ▲ | 6,648 | 3% ▲ | **4,411** | 58% ▲ | 0.039 | -2% ▼ |
| Separations Process Research Unit | 5.185 | -89% ▼ | 167 | -17% ▼ | 59 | -42% ▼ | 0.088 | -81% ▼ |
| SLAC National Accelerator Laboratory | 0.057 | ◊ ▼ | 2,543 | ◊ ▲ | 4 | ◊ ▼ | 0.014 | ◊ ▼ |
| Thomas Jefferson National Accelerator Facility | 0.270 | ◊ ▼ | 1,143 | ◊ ▼ | 20 | ◊ ▼ | 0.014 | ◊ ▼ |
| Uranium Mill Tailings Remedial Action Project | 5.656 | -20% ▼ | 126 | -18% ▼ | 66 | -50% ▼ | 0.086 | 59% ▲ |
| Waste Isolation Pilot Plant | 0.279 | ◊ ▼ | 617 | ◊ ▲ | 17 | ◊ ▼ | 0.016 | ◊ ▲ |
| West Valley Demonstration Project | 33.653 | -18% ▼ | 385 | -36% ▼ | 154 | 5% ▲ | **0.219** | -22% ▼ |
| Service Center Personnel* | 0.091 | ◊ ▼ | 221 | ◊ ▼ | 5 | ◊ ▼ | 0.018 | ◊ ▲ |
| **Totals** | **761.474** | **7%** ▲ | **79,750** | **2%** ▲ | **13,025** | **9%** ▲ | **0.058** | **-1%** ▼ |

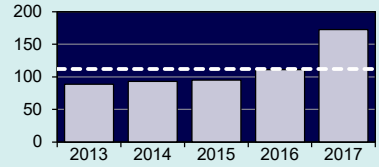
Note: Bold and boxed values indicate the greatest value in each column.
◊ The percentage change from the previous year is not shown because it is not meaningful when the site collective dose is less than 1 person-rem (10 person-mSv).
* Includes personnel at NNSA Albuquerque complex, Oak Ridge, and WIPP in addition to several smaller facilities not associated with a DOE site.

***Exhibit 3-15:***
***Activities Significantly Contributing to Collective TED in 2017, in Descending Order of Collective Dose.***

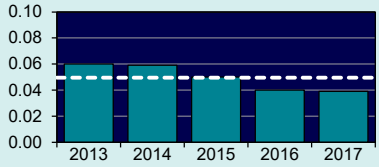
## *Savannah River Site (SRS)*

SRS was constructed during the early 1950s to produce the basic materials used in the fabrication of nuclear weapons, primarily tritium and plutonium-239, in support of our nation's defense programs. Five reactors were built to produce these materials. Also built were a number of support facilities including two chemical separations plants, a heavy water extraction plant, a nuclear fuel and target fabrication facility, a tritium extraction facility, and waste management facilities.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- 3H evaporator pot repair;
- Defense Waste Processing Facility Melter 2 removal and replacement;
- HB-Line glovebox panel replacement;
- Target residual material processing; and
- High radiation area entries in the Savannah River Laboratory for gallery inspections.

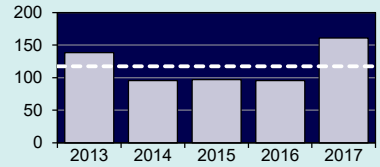
***Changes in Dose***

- The increase in collective dose from 2016 to 2017 can be attributed to more workers engaging in work with a high potential for exposure, specifically those activities listed above.

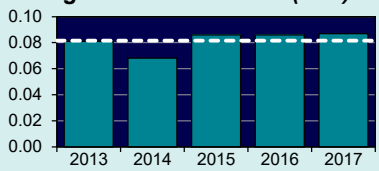
## *Los Alamos National Laboratory (LANL)*

LANL conducts radiological operations in active facilities, storage facilities, facilities with legacy radiological concerns, in addition to operations in inactive facilities and areas destined for decommissioning. Radiological activities include programmatic and production work; facility construction, modification, and maintenance; and research, development, and testing.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Weapons manufacturing and related work at the TA-55 plutonium facility;
- Plutonium-238 work;
- Retrieval, repackaging, and shipping of radioactive waste; and
- Infrastructure support for radiological work and facility maintenance.

***Changes in Dose***

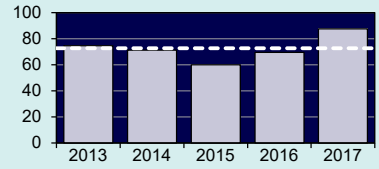
Dose increased in 2017 due to:

- Programmatic work at TA-55 was fully resumed and the facility was operating at normal capacity following a shutdown in 2013; and
- Solid waste handling work that was curtailed in early 2015, due to a contamination release event at the Waste Isolation Pilot Plant (WIPP), resumed in 2017.

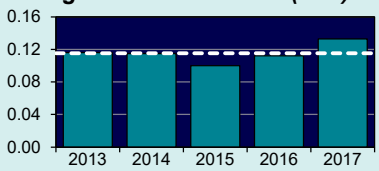
## Oak Ridge: Oak Ridge National Laboratory (ORNL)

ORNL is a multiprogramming science and technology laboratory. ORNL's mission is to deliver scientific discoveries and technical breakthroughs that will accelerate the development and deployment of solutions in clean energy and global security, and in doing so create economic opportunity for the nation. ORNL also performs other work for the DOE, including isotope production, information management, and technical program management, and provides research and technical assistance to other organizations.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Work related to the Spallation Neutron Source and the High Flux Isotope Reactor;
- Nuclear reactor research and radioisotope production; and
- Facility maintenance.

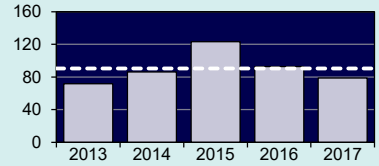
***Changes in Dose***

- Dose increased in 2017 due to maintenance and waste handling activities at neutron research and radiochemistry facilities, and increased project work activities at hot cell and radiochemistry facilities.

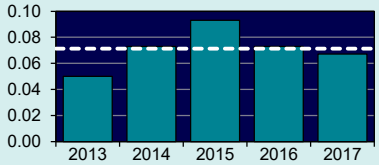
## Idaho Site: Idaho National Laboratory (INL)

The primary focus of activities at INL is nuclear energy research and development. The DOE-ID office oversees three major contracts to ensure that operations and research activities are carried out safely, and in compliance with laws, regulations and contract provisions. The Idaho Cleanup Project (ICP) focuses on addressing legacy wastes resulting from decades of widely-varied work including conventional weapons testing, government-owned research and power reactor development and testing, spent nuclear fuel reprocessing, laboratory research, and defense missions.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Work at the Advanced Test Reactor (ATR) Complex, including experiment system operations, plant maintenance modifications, routine ATR power and outage operations, and Research and Development Operations/Laboratory support;
- Activities at the Materials and Fuel Complex including maintenance at the analytical and radiochemistry laboratories, treatment and storage for waste repackaging, benchtop analyses, fuel handling and a facility ventilation upgrade; and
- Waste handling, consolidation and shipment, decontamination work, and radiography operations.

***Changes in Dose***

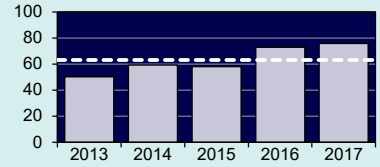
Dose decreased in 2017 due to:

- Decreased experiment handling and shipping operations;
- Waste handling activities and resin transfer operations decreased significantly in 2017, along with the level of radioactivity of the waste that was handled; and
- The installation of new engineering controls related to waste treatment efforts also led to decreased dose.

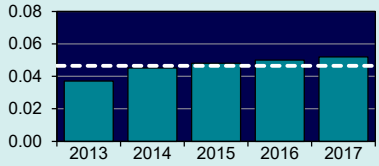
## Oak Ridge: Y-12 National Security Complex (Y-12)

Y-12 is one of four production facilities in the NNSA Nuclear Security Enterprise. The facility's emphasis is the processing and storage of uranium and development of technologies associated with those activities. Y-12 maintains the safety, security, and effectiveness of the U.S. nuclear weapons stockpile and processes highly enriched uranium for the Naval Nuclear Propulsion Program.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Manufacture, processing, and storage of special materials;
- Demolition and cleanup of aging structures; and
- Maintenance of equipment and facilities.

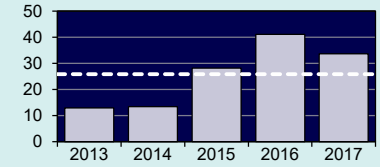
***Changes in Dose***

- In 2017, increased radiological work permit use corresponded to an increased workload and increased number of individuals with a measurable TED.

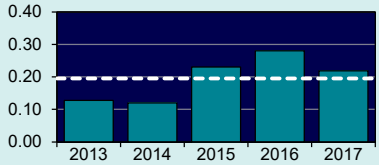
## West Valley Demonstration Project (WVDP)

WVDP is a unique operation within DOE and came into being through the WVDP Act of 1980. The Act requires DOE to be responsible for solidifying the high-level waste and disposing of waste created by the solidification and decommissioning of the facilities used in the process. The land and facilities are not owned by DOE; rather, the project premises are the property of the New York State Energy Research and Development Authority (NYSERDA) and represent only 200 acres of the larger Western New York Service Center, which is approximately 3,300 acres, also owned by NYSERDA. After DOE's responsibilities under the Act are complete, the Act requires that the premises be returned to New York State.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Facility demolition preparation work in the Head End Ventilation, Ventilation Exhaust Cell, Uranium Purification Cell and Uranium Loadout, Vitrification Facility, Extraction Cells, Vent Wash Room, Liquid Waste Cell, and Process Mechanical Cell; and
- Waste operations tasks in lag storage and chemical process cell waste storage area, routine maintenance work on the remote waste handling crane, and Radiological Control Technicians providing support for facility disposition activities.

***Changes in Dose***

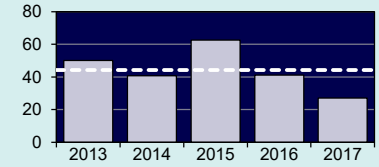
The overall dose decreased in 2017 due to:

- A change in some level of effort in higher dose cell entry and to open air demolition activities of the Vitrification Facility; and
- Focusing on ALARA earlier in the overall planning process.

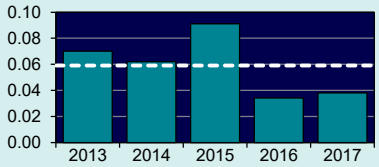
## Hanford: Hanford Site

DOE's Hanford Site sits on 586 square miles in the desert of southeastern Washington State. The area is home to nine former nuclear reactors and their associated processing facilities that were built beginning in 1943. Hanford reactors produced plutonium from 1944 until 1987. Today, Hanford workers are involved in an environmental cleanup project and remediation of the site.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Work activities at the plutonium finishing plant facility;
- Material handling and waste transfer; and
- Facility demolition and site remediation.

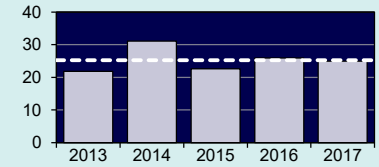
***Changes in Dose***

- The decrease in collective dose at the Plutonium Finishing Plant (PFP) facility was associated with a transition in work activities from source term removal to facility demolition.

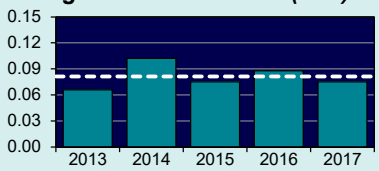
## Pantex Plant

The DOE/NNSA Pantex Plant is the nation's primary facility for the final assembly, disassembly, and maintenance of nuclear weapons. The last new nuclear weapon was completed in 1991. Since then, Pantex has safely dismantled thousands of weapons retired from the stockpile by the military and placed the resulting plutonium pits in interim storage. Pantex has approximately 650 buildings, including specialized facilities in which maintenance, modification, disassembly, and assembly operations are conducted.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Operations that expose workers to large numbers of bare weapon pits containing significant quantities of Special Nuclear Material (SNM); and
- Nuclear explosive assembly/disassembly operations, weapon dismantlement programs, life-extension programs, SNM Component Re-qualification, and SNM staging.

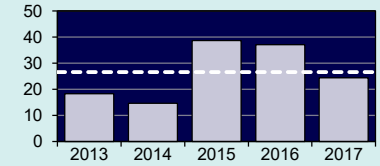
***Changes in Dose***

- The collective dose did not decrease significantly from 2016 to 2017. This small decrease could be attributed to a combination of good ALARA practices and the type of work performed during this reporting period.

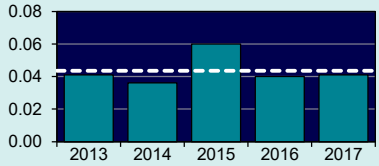
## Hanford: Office of River Protection (ORP)

The DOE ORP mission is to retrieve and treat Hanford's waste and close the tank farms to protect the Columbia River. Chemical and radioactive waste, resulting from more than four decades of plutonium production, is currently stored in 177 large underground tanks. ORP is responsible for the retrieval, treatment, and disposal of this waste. The cornerstone of the tank waste cleanup project is the Waste Treatment Plant (WTP). The WTP will use a technology called vitrification to immobilize chemical and radioactive waste in an exceptionally sturdy form of glass to isolate it from the environment.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Removal and transfer of waste from older single-shell tanks to newer double-shell tanks;
- Maintenance and support of the evaporator which reduces the volume of stored liquid waste by concentrating radioactive waste solutions; and
- Work at the 222-S laboratory.

***Changes in Dose***

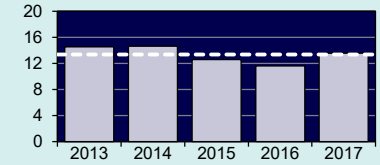
The collective TED decreased in 2017 due to:

- A decrease in work activity as well as the implementation of several techniques to minimize dose during the removal of long length tank equipment; and
- Several Hanford projects continued to operate at minimal levels, resulting in a lower dose.

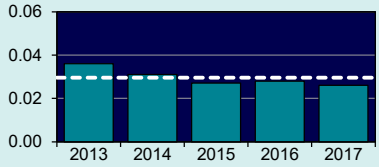
## Hanford: Pacific Northwest National Laboratory (PNNL)

Located in Richland, Washington, PNNL is 1 of 10 national laboratories managed by DOE's Office of Science (SC). The laboratory provides the facilities, unique scientific equipment, and world-renowned scientists and engineers to strengthen U.S. scientific foundations through fundamental research and innovation. The lab also supports Hanford site cleanup efforts by performing scientific and technical evaluations and reviews, and developing and advancing new technologies to address site cleanup challenges.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Work at the Radiochemical Processing Laboratory;
- Radiation detection research; and
- Implementation of security measures for radiological materials of concern.

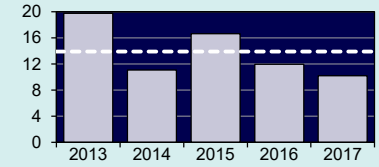
***Changes in Dose***

- The collective dose was higher in 2017 due to an increase in radiological work.

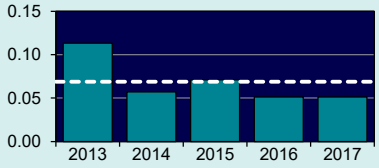
## Fermi National Accelerator Laboratory (Fermilab)

Fermilab provides leadership and resources for qualified researchers to conduct basic research at the frontiers of high-energy particle physics and related disciplines. The primary features on the site include the accelerator complex and associated building infrastructure, an interconnected industrial cooling water system, a housing complex for visiting researchers, row crop agriculture, and natural areas in various states of restoration.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Upgrade and repair activities of the Fermilab accelerator complex;
- Centralized radioactive materials storage area (known as the Railhead) activities; and
- Management and disposal of radioactive waste.

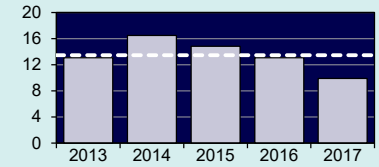
***Changes in Dose***

- The collective TED decreased in 2017 as a result of ALARA practices employed during the completion of upgrades in Booster, Muon Campus, Recycler Ring, and NuMi areas.

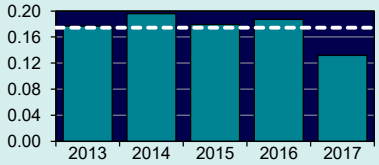
## Argonne National Laboratory (ANL)

ANL is one of DOE's largest national laboratories for scientific and engineering research. The lab's mission is to apply a unique mix of world-class science, engineering, and user facilities to deliver innovative research and technologies. The principal radiological facilities at Argonne are the Advanced Photon Source, a superconducting heavy-ion linear accelerator (LINAC), a 22-MeV pulsed electron LINAC, and several other charged-particle accelerators.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Work supporting the lab's radiological facilities; and
- Material handling, management, storage, and disposition activities associated with the Alpha Gamma Hot Cell Facility, the Waste Management Operations Facility, and the Radioactive Waste Storage Facility.

***Changes in Dose***

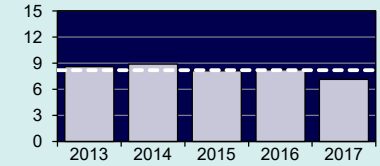
The decreases in collective TED and average measurable TED are attributed to:

- A pause in hot cell work at the Alpha Gamma Hot Cell Facility due to an issue with the clean transfer area door not being operational for approximately 6 months; and
- The Californium Rare Isotope Breeder Upgrade project, originally scheduled to begin in October, was delayed due to a supplier issue with plating the new Californium 252 source.

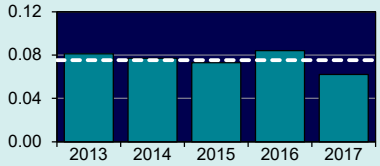
## Lawrence Livermore National Laboratory (LLNL)

LLNL is a DOE facility operated by the Lawrence Livermore National Security, LLC management team, which includes Bechtel, the University of California, BWX Technologies, Washington Group, and Battelle. The site serves as a national resource of scientific, technical, and engineering capability with a special focus on national security. LLNL's mission encompasses such areas as: strategic defense, energy, the environment, biomedicine, technology transfer, education, counter-terrorism, and emergency response. The types of radioactive materials range from tritium to transuranic (TRU); the quantities of each range from nanocuries (i.e., normal environmental background values) to kilocuries.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Radiation producing devices such as X-ray machines, accelerators, and electron-beam welders; and
- Handling a wide range and quantity of radioactive materials.

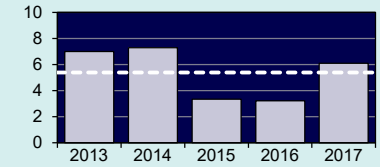
***Changes in Dose***

- The decrease in dose reflects a decrease in the level of exposure associated with the radiological work conducted.

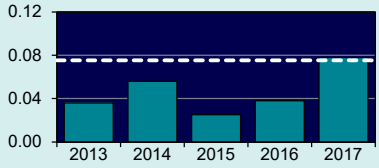
## Brookhaven National Laboratory (BNL)

BNL conducts research in the physical, biomedical, and environmental sciences, as well as in energy technologies and national security. BNL also builds and operates major scientific facilities which are available to university, industry, and government researchers.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Research involving nuclear and particle physics, accelerator science, and biological systems research;
- Facility maintenance and source replacement; and
- Support for the National Aeronautics and Space Administration Space Radiation Laboratory.

***Changes in Dose***

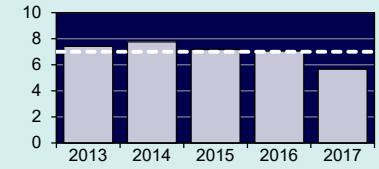
The increase in total dose was primarily due to:

- Increased R&D associated with installation of a new window at the Brookhaven Linear Isotope Producer facility; and
- Cobalt-60 and Cesium-137 source replacements and disposal at the chemistry and biology facilities also contributed to the increased dose.

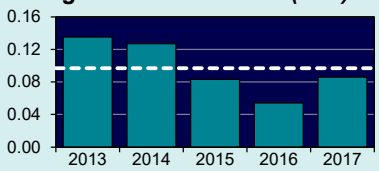
## *Uranium Mill Tailings Remedial Action Project (UMTRA)*

The UMTRA site is located approximately 3 miles northwest of Moab in Grand County, Utah, and includes a former uranium-ore processing facility. The site encompasses 480 acres, of which approximately 130 acres are covered by a uranium mill tailings pile. The UMTRA Project ships two trainloads of tailings each week. The trains have up to 40 railcars, each holding four lidded containers, for a total of about 4,600 tons of tailings per shipment. Tailing shipments began in April 2009 and are expected to continue through 2034.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Maintenance;
- Erosion control measures;
- Tailings excavation and conditioning;
- Ground water remediation; and
- Health and safety oversight.

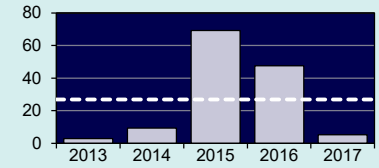
***Changes in Dose***

- Collective dose decreased due to reduced number of monitored workers with a 50% decrease in the number of workers with measurable dose and less radon airborne exposure.

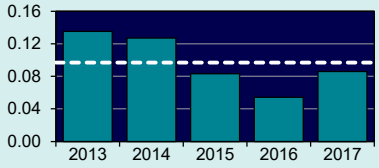
## *Separations Process Research Unit (SPRU)*

SPRU is located at Knolls Atomic Power Laboratory based in upstate New York. Built in the 1940s, the buildings supported the SPRU mission to research the chemical process to extract plutonium from irradiated materials. Although equipment was flushed and drained and bulk waste was removed following the shutdown of the facilities in 1953, residual materials are present in the tanks, buildings H2 and G2, and interconnecting pipe tunnels. The site is currently undergoing a variety of cleanup activities, including demolition, decontamination, and remediation.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Repackaging transuranic waste;
- Processing and shipping low activity water and waste; and
- Surveillance and maintenance of site condition activities.

***Changes in Dose***

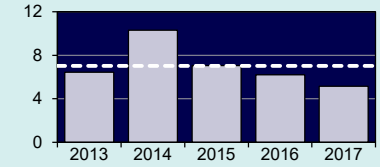
Collective dose decreased due to:

- The completion in 2017 of work in the H2 building for maintenance, process equipment removal, concrete scabbling, and sump debris removal; and
- Decreases were also associated with the completion of work in the G2 building hot cells and the beginning of open air demolition.

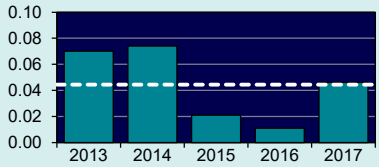
## Paducah Gaseous Diffusion Plant (PGDP)

PGDP is located 3 miles south of the Ohio River and is 12 miles west of Paducah, Kentucky. The plant began enriching uranium in 1952, first for the nation's nuclear weapons program and then for nuclear fuel for commercial power plants. In 1994, the enrichment facilities were leased to United States Enrichment Corporation (USEC). In August 2013, USEC notified DOE that they were discontinuing enrichment operations and planning to de-lease the enrichment facilities.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Environmental cleanup;
- Waste disposition; and
- Decontamination and decommissioning (D&D) of inactive facilities.

***Changes in Dose***

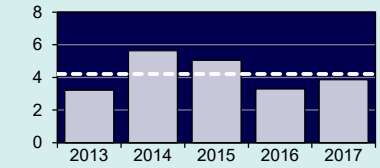
Collective dose decreased due to:

- A decrease in deactivation work activities and the completion of contract work in October 2017 contributed to a decrease in collective TED; and
- An additional factor in the decrease in the collective dose was the decision (based on a study of offsite background variation) to increase the administrative screening level from 5 mrem to 10 mrem. This change simultaneously contributed to a decrease in the collective dose, and an increase in the average measurable dose since doses below 10 mrem are no longer included as measurable doses.

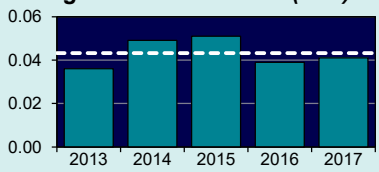
## Nevada National Security Site (NNSS)

NNSS is located approximately 65 miles northwest of Las Vegas. It is a remote facility that covers approximately 1,375 square miles of land. The NNSS has been the primary location for testing nuclear experiments in the continental United States since 1951.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Operation of low-level radioactive and mixed waste disposal facilities;
- Assembly and execution of subcritical experiments, confined critical experiments;
- Assembly/disassembly of special experiments;
- Operation of pulsed X-ray machines and neutron generators;
- Development, testing, and evaluation of radiation detectors; and
- Surface cleanup and site characterization of contaminated land areas.

***Changes in Dose***

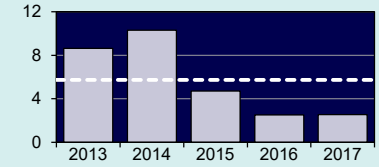
The increase in dose was due to:

- Additional onsite experiments conducted by Livermore and Los Alamos National Laboratory personnel;
- Additional counterterrorism and weapons of mass destruction training classes; and
- Commissioning of a new accelerator and new radiation generating devices within nuclear facilities.

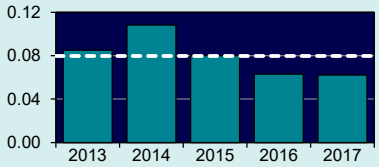
## Portsmouth Gaseous Diffusion Plant (PORTS)

PORTS is located in Pike County, Ohio. PORTS was one of three large gaseous diffusion plants initially constructed to produce enriched uranium to support the nation's nuclear weapons program and later enrich uranium for commercial nuclear reactors. The plant has been shut down and is currently undergoing decontamination and decommissioning (D&D).

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Environmental remediation;
- Facility decontamination; and
- Uranium barter transfers.

***Changes in Dose***

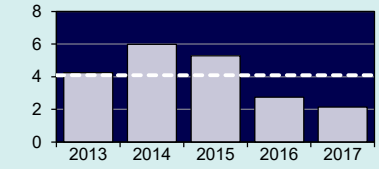
The decrease in dose was due to:

- Work reduction and better work practices resulted in Barter project dose decrease; and
- Dose decreased due to depleted uranium hexafluoride facility shutdown for 2016 and 2017.

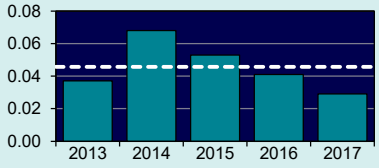
## Sandia National Laboratories (SNL)

SNL's primary mission is ensuring the U.S. nuclear arsenal is safe, secure, and reliable, and can fully support our nation's deterrence policy. Sandia is the engineering arm of the U.S. nuclear weapons enterprise. Sandia's foundation is science-based engineering, in which fundamental science, computer models, and unique experimental facilities come together so researchers can understand, predict, and verify weapon systems performance.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Operation of a research reactor, gamma irradiation facility, hot cell facility, and several pulsed-power accelerators; and
- Conducting light laboratory work involving X-ray machines, tracer radionuclides, and waste operations.

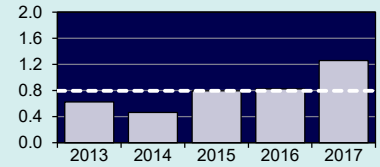
***Changes in Dose***

- Decrease of 2017 dose is attributed to a safety review at the Radioactive and Mixed Waste Management Facility slowing processing significantly for the majority of the year, as compared to that in 2016.

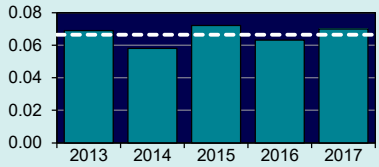
## Lawrence Berkeley National Laboratory (LBNL)

LBNL is a member of the national laboratory system supported by DOE through its Office of Science and is charged with conducting unclassified research across a wide range of scientific disciplines. LBNL employs approximately 4,200 scientists, engineers, support staff, and students.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Fluorine-18 (F-18) research;
- Antineutrino research and experiments; and
- Site inventory of radioactive and nuclear material activities.

***Changes in Dose***

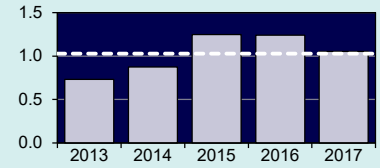
The increase in dose was primarily due to:

- An uptick of isotope production, research on new F-18 targets, and collaboration with Chemical Sciences Division personnel doing research on Lutetium-177m by personnel at the Center for Functional Imaging; and
- Higher dose rates measured on the deflector rails during routine maintenance by B088 maintenance personnel.

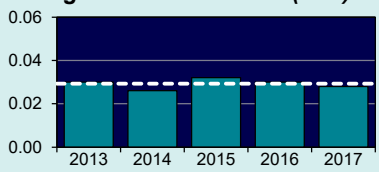
## Ames Laboratory

Ames Laboratory is a government-owned, contractor-operated research facility of the DOE. For over 65 years, the Ames Laboratory has sought solutions to energy-related problems through the exploration of chemical, engineering, materials, mathematical, and physical sciences.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Remediation of radiological legacy contamination; and
- Operation of 23 X-ray systems and one Mossbauer spectroscopy system.

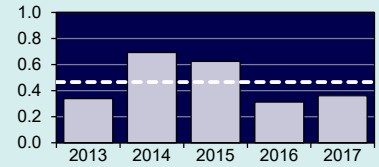
***Changes in Dose***

- Dose decreased due to a limited amount of radioactive material research, as well as the use of microgram quantities of radionuclides.

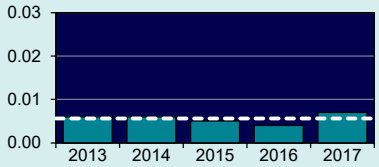
## Princeton Plasma Physics Laboratory (PPPL)

PPPL is a collaborative national center for fusion energy research. The Laboratory advances the coupled fields of fusion energy and plasma physics research and enhances the scientific understanding and key innovations needed to realize fusion as an energy source for the world.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Experimental and Theoretical Fusion research; and
- Plasma research and experiments.

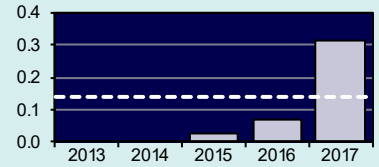
***Changes in Dose***

- Differences are insignificant but likely due to a full year using quarterly dosimeters, where small background statistical variations of minimal exposures accumulated over the course of three months for each quarter.

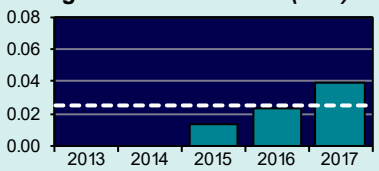
## Office of Secure Transportation (OST)

OST is the NNSA organization tasked to provide secure ground transportation of nuclear weapons, special nuclear material (SNM), nuclear weapon components, and nuclear explosive-like assemblies. OST operates both secure ground transporters and Federal aircraft, which make up the Transportation Safeguards System (TSS). The TSS Federal Agent and vehicle maintenance facilities are located in Oak Ridge, Tennessee, Amarillo, Texas, and Albuquerque, New Mexico. The OST Administrative Headquarters are located on Kirtland Air Force Base in Albuquerque, New Mexico.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Provided secure ground transportation of nuclear weapons, SNM, nuclear weapon components, and nuclear explosive-like assemblies; and
- Tracked and directed cargo loading revisions to minimize radiation exposure.

***Changes in Dose***

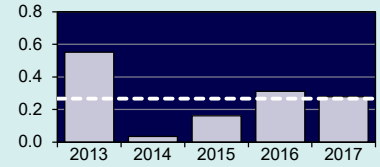
- Differences are insignificant and variations may be attributed to the small number of individuals (less than 10 for each year).

Note: Until 2015, OST was counted among other sites. Only in 2015 was it recorded as an independent entity.

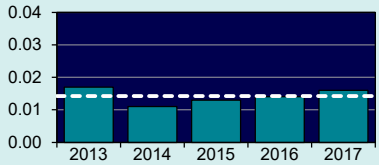
## Waste Isolation Pilot Plant (WIPP)

WIPP is located in the Chihuahuan Desert near Carlsbad, New Mexico. This DOE facility safely disposes of the nation's defense-related TRU radioactive waste. WIPP began disposal operations in March 1999.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Handling and processing of transuranic waste for storage; and
- Managing long-term repository operations.

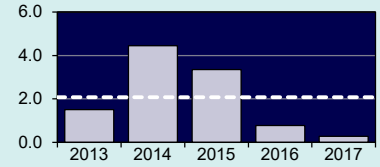
***Changes in Dose***

- Difference in dose is insignificant but decrease is likely due to a shift from decontamination efforts in the WIPP underground to the resumption of routine waste handling activities.

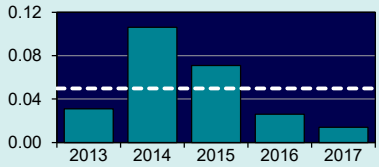
## Thomas Jefferson National Accelerator Facility (TJNAF)

TJNAF is one of 17 national laboratories funded by DOE. TJNAF's primary mission is to conduct basic research of the atom's nucleus using the unique particle accelerator known as the Continuous Electron Beam Accelerator Facility (CEBAF).

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Maintenance, modification, and repair of activated components associated with the CEBAF and other ancillary activities (e.g., transport, storage, and disposal of radioactive materials).

***Changes in Dose***

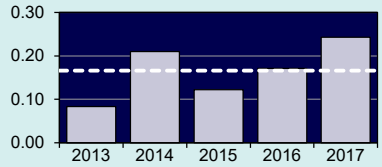
The decrease in total dose was due to:

- The accelerator returning to a commissioning/operational phase in 2017 after the completion of radiological work associated with the CEBAF 12 GeV upgrade;
- Improved procedures and processes for investigating unusual dosimeter results; and
- The number of persons monitored in 2017 was the smallest in the last ten years but the number of individuals with measurable dose was a small fraction of the number of monitored workers and was less in 2017 than in 2016.

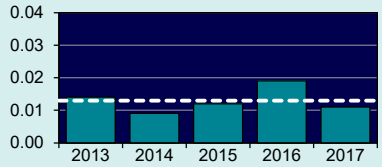
## Oak Ridge: Oak Ridge Institute for Science and Education (ORISE)

ORISE is a DOE institute focusing on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Independent verification activities involving radiological surveys at sites undergoing decommissioning
- Environmental sample processing and radiological protection.

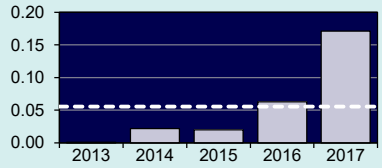
***Changes in Dose***

- The slight increase (0.072 person-rem) was due to more individuals receiving measurable dose at low levels in work areas where the background radiation was slightly higher than normal.

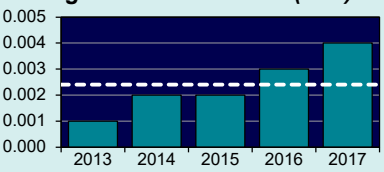
## Kansas City National Security Campus (KC-NSC)

The KC-NSC is responsible for manufacturing and procuring non-nuclear components for nuclear weapons, including electronic, mechanical, and engineered material components. It supports national laboratories, universities, and U.S. industry and is located in Kansas City, Missouri.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Non-destructive testing, telemetry (neutron generators);
- Security operations, depleted uranium operations; and
- Legacy part refurbishment and waste management.

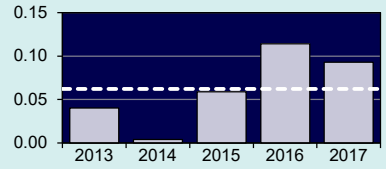
***Changes in Dose***

- A small increase in collective and average measurable dose was likely due to increased production associated with an on-going weapons Life Extension Program.

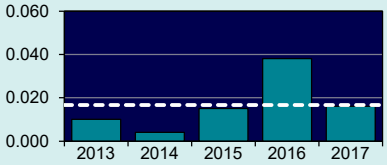
## Oak Ridge: East Tennessee Technology Park (ETTP)

ETTP was originally named the Oak Ridge Gaseous Diffusion Plant. As part of the Manhattan Project, the Plant was designed to produce enriched uranium for use in atomic weapons operations during World War II. After the war, this Plant was renamed the Oak Ridge K-25 Site and produced enriched uranium for the commercial nuclear power industry from 1945 to 1985. In 1987, DOE renamed the site ETTP and began a major environmental cleanup project with the long-term goal of converting ETTP into a private industrial park.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Continuation of ongoing cleanup activities.

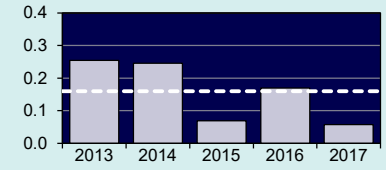
***Changes in Dose***

- Small decrease of dose reported but due to the small number of individuals with measurable dose and the low dose, these changes are not significant.

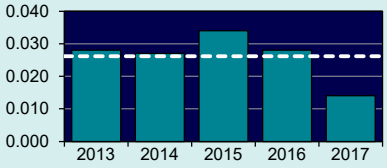
## SLAC National Accelerator Laboratory (SLAC)

SLAC, which opened in 1962, is 1 of 10 DOE Office of Science laboratories and is operated by Stanford University on behalf of DOE. Originally a premier high-energy particle accelerator laboratory, SLAC has grown into a state-of-the-art photon science laboratory. SLAC's scientific mission has diversified from an original focus on particle physics and accelerator science to include cosmology, materials and environmental sciences, biology, chemistry, and alternative energy research.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Operation of the LINAC Coherent Light Source - the world's first hard X-ray free electron laser;
- Operation of the Stanford Synchrotron Radiation Lightsource - a pioneering synchrotron radiation facility; and
- Operation of the Stanford positron-electron asymmetric ring (SPEAR3), and a separate, shorter linear accelerator (LINAC), and a booster ring for injecting accelerated beams of electrons into SPEAR3.

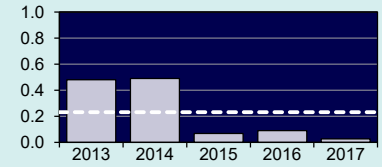
***Changes in Dose***

- The collective dose decreased in 2017 and reflects normal routine operations and normal variations given the limited number of individuals with measurable dose and the very low doses.

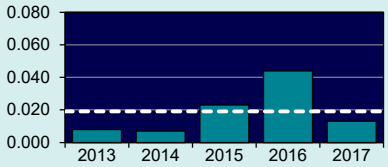
## Energy Technology Engineering Center (ETEC)

ETEC is located within area IV of the Santa Susana Field Laboratory. The laboratory comprises four discrete operational areas with two adjacent undeveloped properties. In 1988, DOE decided to close the remaining ETEC operations. ETEC is currently in a safe shutdown mode, pending the completion of the Environmental Impact Statement.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Disposition of government property;
- Cleanup of facilities, demolition of facilities, and site restoration;
- Area IV is undergoing characterization for cleanup of the area; and
- Investigation and remediation of soil and groundwater.

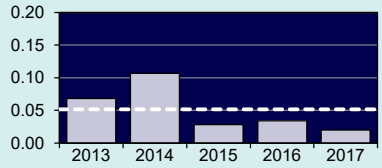
***Changes in Dose***

- Changes in dose are low and insignificant

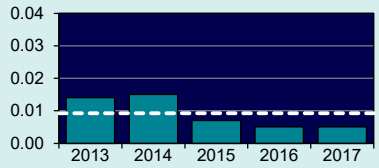
## National Renewable Energy Laboratory (NREL)

NREL focuses on creative answers to today's energy challenges. From fundamental science and energy analysis to validating new products for the commercial market, NREL researchers are dedicated to transforming the way the world uses energy. With more than 35 years of successful innovation in energy efficiency and renewable energy, NREL discoveries provide sustainable alternatives for powering homes, businesses, and transportation systems.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Electron microscopy staining; and
- Operation of analytical and process equipment containing sealed sources.

***Changes in Dose***

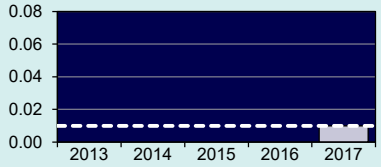
The slight decrease in dose for 2017 is not significant, but is likely due to:

- Having only small quantities of low-level radioactive waste in storage; and
- A decrease in work involving radiation exposure and decontamination activities. Due to the small number of individuals with measurable dose these small differences may also be just normal variations.

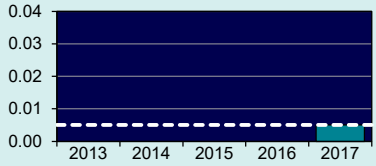
## Grand Junction Site

The Grand Junction disposal site was transferred to the Office of Legacy Management in 2003. Legacy Management manages the site according to a site-specific Long-Term Surveillance and Maintenance Plan.

***Collective TED (person-rem)***




***Average Measurable TED (rem)***




***Activities Involving Radiation Exposure***

- Conducting annual sampling of groundwater and surface water, validating the analytical data generated from the annual sampling event;
- Conducting an annual site inspection and preparing an inspection report; and
- Monitoring well maintenance.

***Changes in Dose***

- All doses received were from routine field activities performed by Legacy Management personnel and were very low.

### 3.4.4 Summary by Program Office

DOE has divided the responsibility of managing its missions among specific program offices. A site may include facilities or project areas that perform work in support of the mission of multiple program offices. In these cases, the dose records are separated by the reporting organization and assigned to the corresponding program office. For this reason, some sites will have portions of the collective dose shown under more than one program office.

*Exhibit 3-15* shows the collective TED, number of individuals with measurable TED, and the average measurable TED by DOE program office. The Office of Environmental Management (EM) and the NNSA account for the largest percentages of the collective TED (47 and 36 percent, respectively). The mission of EM is to complete the safe cleanup of the environmental legacy brought about from five decades of nuclear weapons development and government-sponsored nuclear energy research. NNSA is responsible for the management and security of the nation's nuclear weapons, nuclear nonproliferation, and naval reactor programs, as well as responding to radiological emergencies and the transportation of nuclear weapons and SNM. These offices account for 83 percent of the collective TED at DOE.

The primary sites contributing to the collective TED within EM are SRS and Idaho. For NNSA, the primary contributors are LANL and Y-12.

A more detailed breakdown of the exposure information by site, program office, and contractor is available at https://energy.gov/ehss/occupational-radiation-exposure in the Appendices section of the Annual Report.

***Exhibit 3-16:***
***Program Office Dose Data, 2017.***

| Program Office | Collective TED (person-rem) | Percent Change from 2016 | Number with Meas. Dose (TED) | Percent Change from 2016 | Avg. Meas. TED (rem) | Percent Change from 2016 |
|---|---|---|---|---|---|---|
| **Office of Energy Efficiency and Renewable Energy (EE)** | | | | | **Total Monitored =** | **11*** |
| National Renewable Energy Laboratory | 0.020 | ◊ ▼ | 4 | ◊ ▼ | 0.005 | ◊ ▲ |
| **EE Totals** | **0.020** | ◊ ▼ | **4** | ◊ ▼ | **0.005** | ◊ ▲ |
| **Office of Environmental Management (EM)** | | | | | **Total Monitored =** | **22,395*** |
| East Tennessee Technology Park | 0.093 | ◊ ▼ | 6 | ◊ ▲ | 0.016 | ◊ ▼ |
| Energy Technology Engineering Center | 0.026 | ◊ ▼ | 2 | ◊ - | 0.013 | ◊ ▼ |
| Hanford Site | 27.003 | -34% ▼ | 717 | -41% ▼ | 0.038 | 12% ▲ |
| Idaho Site (ICP, AMWTP and DOE IOO) | 48.825 | -13% ▼ | 641 | 1% ▲ | 0.076 | -14% ▼ |
| Oak Ridge National Laboratory | 35.048 | 19% ▲ | 222 | 8% ▲ | 0.158 | 10% ▲ |
| Office of River Protection | 24.387 | -34% ▼ | 597 | -36% ▼ | 0.041 | 2% ▲ |
| Paducah Gaseous Diffusion Plant | 5.159 | -17% ▼ | 113 | -80% ▼ | 0.046 | **312%** ▲ |
| Portsmouth Gaseous Diffusion Plant | 2.553 | 2% ▲ | 41 | 3% ▲ | 0.062 | -1% ▼ |
| Savannah River Site | **172.546** | **55%** ▲ | **4,411** | **58%** ▲ | 0.039 | -2% ▼ |
| Separations Process Research Unit | 5.185 | -89% ▼ | 59 | -42% ▼ | 0.088 | -81% ▼ |
| Service Center Personnel* | 0.091 | ◊ ▼ | 5 | ◊ ▼ | 0.018 | ◊ ▲ |
| Uranium Mill Tailings Remedial Action Project | 5.656 | -20% ▼ | 66 | -50% ▼ | 0.086 | 59% ▲ |
| Waste Isolation Pilot Plant | 0.279 | ◊ ▼ | 17 | ◊ ▼ | 0.016 | ◊ ▲ |
| West Valley Demonstration Project | 33.653 | -18% ▼ | 154 | 5% ▲ | **0.219** | -22% ▼ |
| **EM Totals** | **360.504** | **-5%** ▼ | **7,051** | **4%** ▲ | **0.051** | **-9%** ▼ |
| **Office of Legacy Management (LM)** | | | | | **Total Monitored =** | **22*** |
| Grand Junction Site | 0.010 | ◊ ▲ | 2 | ◊ ▲ | 0.005 | ◊ ▲ |
| **LM Totals** | **0.010** | ◊ ▲ | **2** | ◊ ▲ | **0.005** | ◊ ▲ |
| **National Nuclear Security Administration (NNSA)** | | | | | **Total Monitored =** | **34,044*** |
| Kansas City National Security Campus | 0.171 | ◊ ▲ | 44 | ◊ ▲ | 0.004 | ◊ ▲ |
| Lawrence Livermore National Laboratory | 7.134 | -13% ▼ | 115 | 17% ▲ | 0.062 | -26% ▼ |
| Los Alamos National Laboratory | **160.772** | **68%** ▲ | **1,850** | **67%** ▲ | **0.087** | 1% ▲ |
| Office of Secure Transportation | 0.311 | ◊ ▲ | 8 | ◊ ▲ | 0.039 | ◊ ▲ |
| Nevada National Security Site | 3.858 | 17% ▲ | 94 | 12% ▲ | 0.041 | 5% ▲ |
| Pantex Plant | 24.986 | -4% ▼ | 333 | 13% ▲ | 0.075 | -15% ▼ |
| Sandia National Laboratories | 2.146 | -22% ▼ | 73 | 7% ▲ | 0.029 | -27% ▼ |
| Y-12 National Security Complex | 75.890 | 4% ▲ | 1,453 | ◊ ▼ | 0.052 | **5%** ▲ |
| **NNSA Totals** | **275.268** | **32%** ▲ | **3,970** | **27%** ▲ | **0.069** | **4%** ▲ |
| **Office of Nuclear Energy, Science and Technology (NE)** | | | | | **Total Monitored =** | **5,070*** |
| Idaho National Laboratory | 30.121 | -18% ▼ | 536 | -16% ▼ | 0.056 | -2% ▼ |
| **NE Totals** | **30.121** | **-18%** ▼ | **536** | **-16%** ▼ | **0.056** | **-2%** ▼ |
| **Office of Science (SC)** | | | | | **Total Monitored =** | **18,208*** |
| Ames Laboratory | 1.053 | -15% ▼ | 38 | -7% ▼ | 0.028 | -8% ▼ |
| Argonne National Laboratory | 9.885 | -24% ▼ | 75 | 7% ▲ | **0.132** | -29% ▼ |
| Brookhaven National Laboratory | 6.087 | **89%** ▲ | 78 | -7% ▼ | 0.078 | **104%** ▲ |
| Fermi National Accelerator Laboratory | 10.210 | -14% ▼ | 201 | -13% ▼ | 0.051 | -1% ▼ |
| Lawrence Berkeley National Laboratory | 1.257 | 53% ▲ | 18 | **38%** ▲ | 0.070 | 10% ▲ |
| Oak Ridge Institute for Science and Education | 0.243 | ◊ ▲ | 23 | ◊ ▲ | 0.011 | ◊ ▼ |
| Oak Ridge National Laboratory | **52.573** | 32% ▲ | 439 | 7% ▲ | 0.120 | 24% ▲ |
| Pacific Northwest National Laboratory | 13.555 | 17% ▲ | **517** | 23% ▲ | 0.026 | -5% ▼ |
| Princeton Plasma Physics Laboratory | 0.361 | ◊ ▼ | 49 | ◊ ▼ | 0.007 | ◊ ▲ |
| SLAC National Accelerator Laboratory | 0.057 | ◊ ▼ | 4 | ◊ ▼ | ◊ | ◊ ▼ |
| Thomas Jefferson National Accelerator Facility | 0.270 | ◊ ▼ | 20 | ◊ ▼ | 0.014 | ◊ ▼ |
| **SC Totals** | **95.551** | **15%** ▲ | **1,464** | **5%** ▲ | **0.065** | **9%** ▲ |

Note: Bold and boxed values indicate the greatest value in each column.
◊ The percentage change from the previous year is not shown because it is not meaningful when the site collective dose is less than 1 person-rem (10 person-mSv).
* Individuals who worked at more than one program office are represented within each grouping; therefore, the total monitored values will not match the annual number of workers monitored.

## 3.5 Transient Individuals

For the purpose of this report, a DOE site is defined as a geographic location. Transient individuals, or transients, are defined as individuals who are monitored at more than one DOE site during the calendar year. During the year, some individuals performed work at multiple sites and, therefore, had more than one monitoring record reported to the repository. In addition, some individuals transferred from one site to another. This section presents information on transient individuals to determine the extent to which individuals traveled from site to site and to examine the doses received by these individuals. *Exhibit 3-16* shows the dose distribution and total number of transient individuals from 2013 to 2017. Over the past 5 years, the records of transient individuals have averaged 3 percent of the total records for all monitored individuals. These individuals received, on an average, 3.1 percent of the collective TED. The collective TED for transients decreased from 23.5 person rem (235 person-mSv) in 2016 to 20.0 person-rem (200 person-mSv) in 2017. The average measurable TED decreased 12 percent from 0.049 rem (0.490 mSv) in 2016 to 0.043 rem (0.430 mSv) in 2017. The decrease of the average measurable TED was a result of the 3 percent decrease in the number of transient individuals with measurable dose (484 in 2016 to 469 in 2017) and the 15 percent decrease in the collective TED. Since 1993, the percentages have remained relatively constant.

The tracking and analysis of transient workers are important aspects of the AU REMS project. While each site is responsible for monitoring individuals during their work at that site, the REMS project collects dose records from all sites and verifies that individuals do not exceed regulatory limits by accruing doses at multiple facilities. Although the number of transient individuals and average doses have been low, the examination of these records remains an important function of AU in assessing performance of DOE worker health and safety programs.

## 3.6 Historical Data

In order to provide historical context for radiation exposure data at DOE, it is useful to include information prior to the past 5 years, as presented in this report. *Exhibit 3-17* and *Exhibit 3-18* show a summary of occupational exposures back to 1974, when the Atomic Energy Commission split into the NRC and the Energy Research and Development Administration, which subsequently became DOE. *Exhibit 3-17* and *Exhibit 3-18* show the collective dose, average measurable dose, and number of workers with a measurable dose from 1974 to 2017. As can be seen from the graphs, all three parameters decreased dramatically between 1986 and 1993. The main reasons for this large decrease were the shutdown of facilities within the weapons complex and the end of the Cold War era, which shifted the DOE mission from weapons production to shutdown, stabilization, and Decontamination and Decommissioning (D&D), activities.

***Exhibit 3-17:***
***Dose Distribution of Transient Individuals, 2013–2017.***

| | Dose Ranges (TED in rem) | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|
| Transients | Less than measurable | 1,501 | 2,157 | 2,151 | 2,014 | 2,035 |
| | Measurable <0.100 | 371 | 380 | 360 | 422 | 429 |
| | 0.100–0.250 | 26 | 41 | 35 | 46 | 24 |
| | 0.250–0.500 | 14 | 12 | 10 | 14 | 12 |
| | 0.500–0.750 | 1 | | 3 | 1 | 3 |
| | 0.750–1.000 | | 1 | 2 | 1 | 1 |
| | 1.0–2.0 | | | | | |
| | >2.0 | | | | | |
| | Total number of individuals monitored* | 1,913 | 2,591 | 2,561 | 2,498 | 2,504 |
| | Number with measurable dose | 412 | 434 | 410 | 484 | 469 |
| | % with measurable dose | 22% | 17% | 16% | 19% | 19% |
| | Collective TED (person-rem) | 21.053 | 21.400 | 21.636 | 23.491 | 20.010 |
| | Average measurable TED (rem) | 0.051 | 0.049 | 0.053 | 0.049 | 0.043 |
| All DOE | Total number of records for monitored individuals | 71,599 | 75,470 | 75,587 | 77,836 | 79,888 |
| | Number of individuals with measurable dose | 9,906 | 9,508 | 10,033 | 11,988 | 13,025 |
| | % of total monitored individuals who are transient | 2.7% | 3.4% | 3.4% | 3.2% | 3.1% |
| | % of the number of individuals with measurable dose who are transient | 4.2% | 4.6% | 4.1% | 4.0% | 3.6% |

* Total number of individuals represents the number of individuals monitored and not the number of records.

***Exhibit 3-18:***
***Collective Dose and Average Measurable Dose, 1974–2017.***

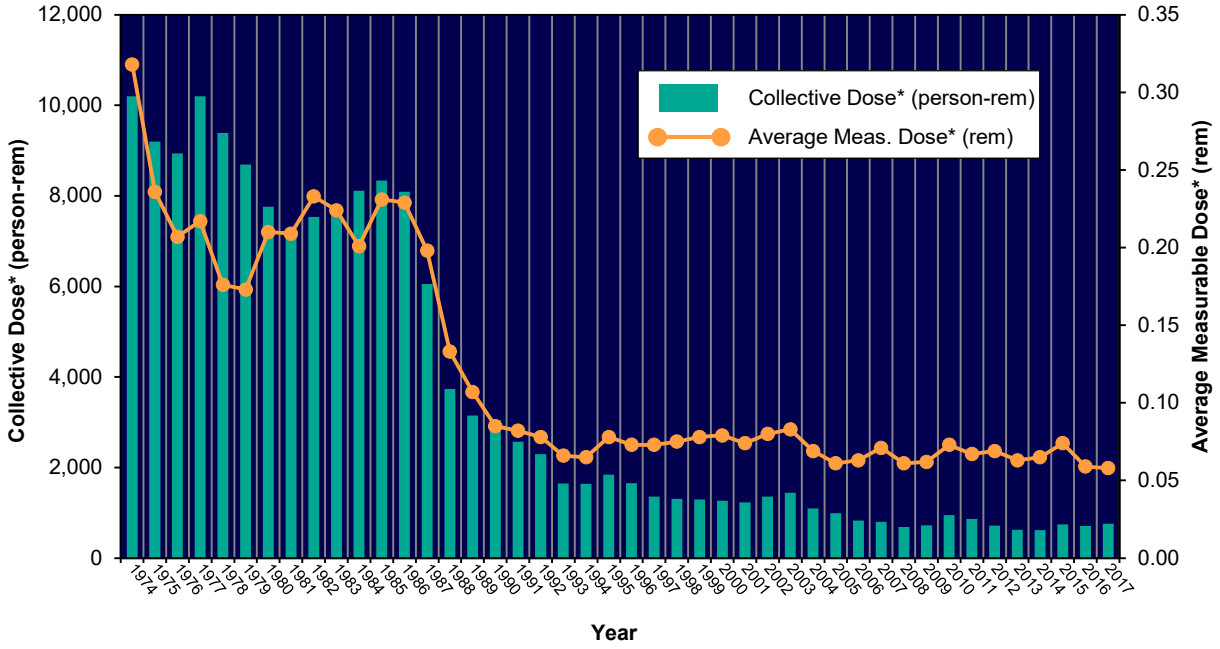
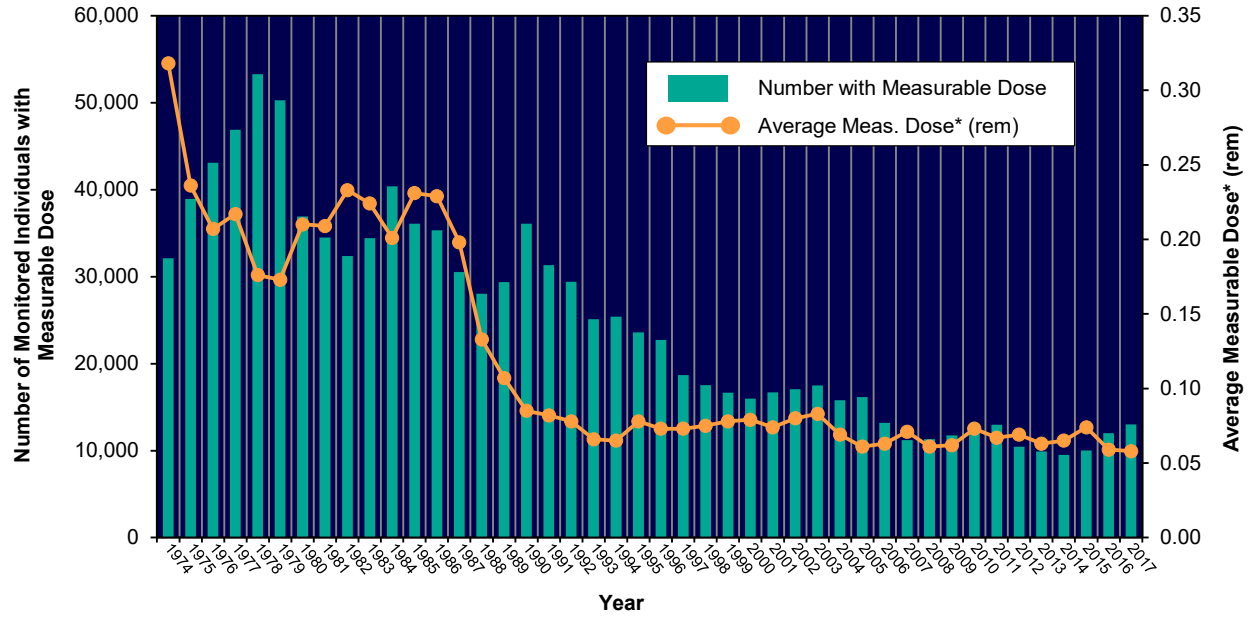



***Exhibit 3-19:***
***Number of Workers with Measurable Dose and Average Measurable Dose, 1974–2017.***




* 1974–1989 collective dose = DDE
1990–1992 collective dose = DDE + AEDE
1993–2009 collective dose = DDE + CEDE
2010–2017 collective dose = ED + CED

1946–1974 Atomic Energy Commission (AEC)
1974–1977 Energy Research and Development Administration (ERDA)
1977–Present Department of Energy (DOE)

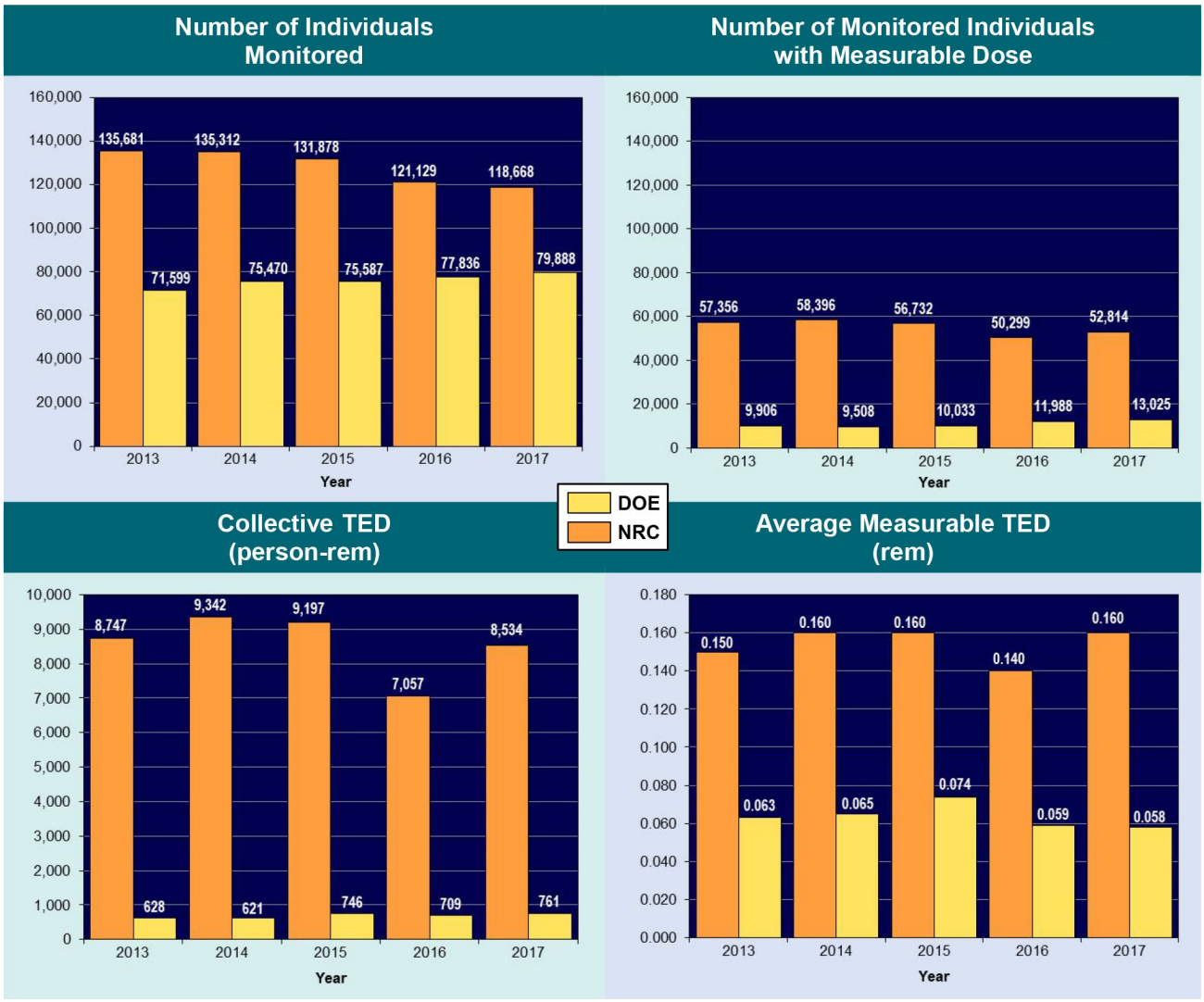
## 3.7 DOE Occupational Dose in Relation to Other Activities

### 3.7.1 Activities Regulated by the U.S. Nuclear Regulatory Commission

The purpose of this section is to provide a general comparison of DOE occupational radiation exposure to other industrial and governmental organizations in order to gain an understanding of the relative scale of the radiation exposure at DOE operations. The 2017 report compares the DOE occupational exposure to activities regulated by the NRC. While the mission of DOE is broad in scope and includes activities from energy research to national defense, NRC-licensed activities are dominated by radiation exposure received at commercial nuclear power plants. For NRC, reactor operations account for approximately 75 percent of the collective TED, while industrial radiographers, manufacturers, and distributors of radiopharmaceuticals; independent spent fuel storage installations; and fuel cycle licensees comprise the remainder.

The DOE and NRC occupational exposure data shown in *Exhibit 3-19* cover the past 5 years (2013 to 2017). While the number of workers monitored at NRC and DOE are comparable over the past 5 years, the number of individuals with a measurable dose at DOE was 20 percent of the NRC total for this time period. The percentages of DOE's collective dose (TED) and average measurable dose (TED) were 8 percent and 41 percent of the NRC totals, respectively.

***Exhibit 3-20:***
***Comparison of Occupational Exposure for DOE and NRC, 2013–2017.***



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Section Four

# 4 ALARA Activities at DOE



Descriptions of ALARA activities at DOE are provided on the DOE web site: https://www.energy.gov/ehss/occupational-radiation-exposure-publications for the purpose of sharing strategies and techniques that have shown promise in reducing the radiation exposure and to facilitate the dissemination among DOE radiation protection managers and others. Readers should be aware that the project descriptions are voluntarily submitted from the sites and are not independently verified or endorsed by DOE. Program and site offices and contractors who are interested in benchmarks of success and continuous improvement in the context of integrated safety management and quality are encouraged to provide input.

## 4.1 Submitting ALARA Project Descriptions for Future Reports

Individual project descriptions may be submitted to the DOE Office of ES&H Reporting and Analysis through the REMS web site. The submissions should describe the process in sufficient detail to provide a basic understanding of the project, the radiological concerns, and the activities initiated to reduce dose. The web site provides a form to collect the following information about the project:

- Mission statement;
- Project description;
- Radiological concerns;
- Total collective dose for the project;
- Dose rate to exposed workers before and after exposure controls were implemented;
- Information on how the process implemented ALARA techniques in an innovative or unique manner;
- Estimated dose avoided;
- Project staff involved;
- Approximate cost of the ALARA effort;
- Impact on work processes, in person-hours if possible (may be negative or positive);
- Figures and/or photos of the project or equipment (electronic images if available); and
- Point of contact for follow-up by interested professionals.

The REMS web page for submitting ALARA project descriptions can be accessed on the internet at:

**https://energy.gov/ehss/downloads/line-alara-project-submittal-form-report-alara-project-descriptions-rems**

## 4.2 Operating Experience Program

DOE has a mature operating experience program, which has been enhanced from the lessons learned program that was initially developed in 1994. The current DOE operating experience program is described in DOE O 210.2A, *DOE Corporate Operating Experience Program* [9]. The objectives of the operating experience program are to institute a DOE-wide program for the management of operating experience to prevent adverse operating incidents and to expand the sharing of good work practices among DOE sites. The program provides a systematic review, identification, collection, screening, evaluation, and dissemination of operating experience from U.S. and foreign government agencies and industry, professional societies, trade associations, national academies, universities, and DOE and its contractors. DOE Headquarters takes corporate responsibility for identifying, analyzing, and sharing operating experience information. Operating experience/lessons learned provided by DOE field sites optimizes the knowledge gained and shares it through various products, including a corporate database.

DOE posts operating experience information and links to other operating experience resources on the internet. DOE uses the internet to disseminate information so that DOE and external entities may improve the health and safety aspects of operations within their facilities, including reducing the number of accidents and injuries.

For further information contact:

**https://energy.gov/ehss/corporate-operating-experience-program**

**1000 Independence Avenue, SW**
**Washington, D.C. 20585-1290**
**E-mail: Ashley.Ruocco@hq.doe.gov**

# Conclusions



In 2017, DOE facilities continued to comply with DOE dose limits and ACL and minimize exposures to individuals. Only 16 percent of the monitored workers received a measurable dose, and the average measurable dose received was only 1 percent of the DOE limit. The collective dose increased by 7 percent and the number of individuals with measurable dose increased by 9 percent. The increase in the number of individuals with measurable dose was the result of increased work activities involving radioactive materials at SRS, Oak Ridge, and LANL. See *Exhibit 5-1* below for summary data.

The collective TED for all DOE facilities increased by more than 52 person-rem (520 person-mSv) from 2016 to 2017. Much of the increase in collective dose has been attributed to increased work activities such as waste handling and D&D.

The collective dose at DOE facilities has decreased by 91 percent since 1986. This coincides with the end of the Cold War era, which shifted the DOE mission from weapons production to stabilization, waste management, and environmental remediation activities, along with the consolidation and remediation of facilities across the complex to meet the new mission. As DOE has become more involved in the new missions, the collective and average doses have been relatively low. Also, in alignment with the change in mission, regulations and requirements have been modified (see Section 2) that reinforce DOE's focus on ALARA practices and risk reduction to lowering occupational radiation dose.

***Exhibit 5-1: 2017 Radiation Exposures Summary.***

- No doses exceeded the DOE occupational dose limit of 5 rem (50 mSv) TED or the DOE ACL of 2 rem (20 mSv) TED in 2017.
- The collective TED increased 7 percent from 709 person-rem (7,090 person-mSv) in 2016 to 761 person-rem (7,610 person-mSv) in 2017.
- The sites contributing the majority of the collective TED were (in descending order): Savannah River Site (SRS), Oak Ridge (OR), Los Alamos National Laboratory (LANL), Idaho, and Hanford. These sites accounted for 84 percent of the collective TED in 2017. The collective TED increased at LANL, SRS and Oak Ridge. The increase at LANL was due largely to increased work activities at TA-55 plutonium facility operations which were fully resumed following the 2013 shutdown. The increase SRS can be attributed to workers engaging in work with a high potential for exposure, and at Oak Ridge, the increase in collective TED is attributed to increased project work activities at hot cell and radiochemistry facilities, and maintenance and waste handling activities at neutron research and radiochemistry facilities. The collective TED decreased at Hanford and Idaho. The decrease at Hanford was due to a change in work activities at the plutonium finishing plant facility (PFP). The collective TED at Idaho decreased for a variety of reasons including decreased experiment handling and shipping operations; and the installation of new engineering controls related to waste treatment efforts.
- The collective CED (internal exposure) increased by 7 percent from 61.5 person-rem (615 person-mSv) in 2016 to 66.0 person-rem (660 person-mSv) in 2017, mainly as a result of an increase in internal dose at Y-12. Uranium-234 (U-234) accounted for the largest percentage of the collective CED, with over 99 percent of this dose accrued at Y-12.
- The collective TED for transient workers (individuals monitored at more than one DOE site) decreased by 15 percent from 23.5 person-rem (235 person-mSv) in 2016 to 20.0 person-rem (200 person-mSv) in 2017.

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# Glossary

**Administrative control level (ACL)**
A dose level that is established below the DOE dose limit in order to administratively control exposures. ACLs are multi-tiered, with increasing levels of authority required to approve a higher level of exposure.

**ALARA**
Acronym for "as low as reasonably achievable," which is the approach to radiation protection to manage and control exposures (both individual and collective) to the workforce and the general public to as low as reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit, but a process with the objective of attaining doses as far below the applicable limits as is reasonably achievable.

**Average measurable dose**
Dose obtained by dividing the collective dose by the number of individuals who received a measurable dose. This is the average most commonly used in this and other reports when examining trends and comparing doses received by workers, because it reflects the exclusion of those individuals receiving a less than measurable dose. In this report, average measurable dose is calculated for TED and CED.

**Collective dose**
As used in this report, the term "collective dose" is the sum of doses to all individuals in a population for a period of time. The general term "collective dose" is used whenever the dose may refer to more than one type of dose. In cases where the type of dose is specified, the term "collective" is followed by the type of dose such as the TED, CED, or photon. In all cases, the population is the group of DOE workers that were monitored for occupational radiation exposure, and the period of time is the monitoring year. Collective dose is expressed in units of person-rem.

**Committed effective dose (CED) ($H_E$,50)**
The sum of the committed equivalent doses to various tissues or organs in the body ($H_T$,50), each multiplied by the appropriate tissue weighting factor ($w_T$) (i.e., $H_E,50 = w_T H_T,50$). CED is expressed in units of rem.

**Committed equivalent dose (CEqD) ($H_T$,50)**
The equivalent dose calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. CEqD is expressed in units of rem.

**DOE site**
A geographic location operated under the authority of the DOE.

**Effective dose**
The summation of the products of the equivalent dose received by specified tissues or organs of the body ($H_T$) and the appropriate tissue weighting factor ($w_T$) – that is, Effective dose = $\Sigma w_T H_T$. It includes the dose from radiation sources internal and/or external to the body. For purposes of compliance with this part, equivalent dose to the whole body may be used as effective dose for external exposures. The effective dose is expressed in units of rem (or Sievert [Sv]).

**Equivalent dose (EqD)**
The product of average absorbed dose ($D_{T,R}$) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor ($w_R$). For external dose, the EqD to the whole body is assessed at a depth of 1 cm in tissue; the EqD to the lens of the eye is assessed at a depth of 0.300 cm in tissue; and the EqD to the extremity and skin is assessed at a

depth of 0.007 cm in tissue. The mathematical term is $H_T$, while the abbreviation EqD is used in this report and in the REMS reporting requirements for this data element. EqD is expressed in units of rem (or Sv).

**Exposure**
Occupational exposure means an individual's exposure to ionizing radiation (external and internal) as a result of that individual's work assignment.

Occupational exposure does not include planned special exposures, exposure received as a medical patient, background radiation, or voluntary participation in medical research programs.

**Hanford**
This term is used to describe the entire reservation and all activities at this geographic location. It includes all cleanup activities at the reactors at the "Hanford Site," ORP, and PNNL. This term is used when we are including Hanford Site, ORP, and PNNL.

**Hanford Site**
All activities at, and cleanup of, the reactors and 100–400 areas at the reservation. Does not include ORP and PNNL.

**Office of River Protection (ORP)**
Tank farm and liquid waste cleanup to protect the Columbia River.

**Pacific Northwest National Laboratory (PNNL)**
The national laboratory involved in a broad range of scientific research.

**Measurable dose**
A dose greater than zero rem (not including doses reported as "not detectable").

**Member of the public**
Any individual not occupationally exposed to radiation or radioactive material, which either is not a DOE general employee or is an off duty DOE general employee. The definition of general employee is specified in 10 CFR 835.

**Number of individuals with measurable dose**
The subset of all monitored individuals who receive a measurable dose (greater than the limit of detection for the monitoring system). Many personnel are monitored as a matter of prudence and may not receive a measurable dose. For this reason, the number of individuals with measurable dose is presented in this report as a more accurate indicator of the exposed workforce. The number of individuals represents the number of dose records reported. Some individuals may be counted more than once if multiple dose records are reported for the individual during the year.

**Occupational dose**
Occupational dose is an individual's ionizing radiation dose (external and internal) as a result of that individual's work assignment. Occupational exposure does not include doses received as a medical patient or doses resulting from background radiation or participation as a subject in medical research programs.

**Person-rem**
The unit of measurement used for the collective dose to all DOE employees, contractors, and subcontractors.

**Rem**
A unit of dose derived from the phrase roentgen equivalent man. The rem is equal to 0.010 sievert, which is the international unit of measurement for radiation exposure.

**Scabbling**
A mechanical process of removing a thin layer of concrete from a structure, typically achieved by compressed air-powered machines.

**Total effective dose (TED)**
The sum of the effective dose from external sources and the CED from intakes of radionuclides during the monitoring period. The internal dose component of TED changed from the annual effective dose equivalent to the committed effective dose equivalent (CEDE) in 1993 and from CEDE to CED in 2007.

**Total number of records for monitored individuals**
All individuals who are monitored and reported to the DOE Headquarters database system. This includes DOE employees, contractors, subcontractors, and members of the public monitored during a visit to a DOE site. The number of individuals represents the number of dose records reported. Some individuals may be counted more than once if multiple dose records are reported for the individual during the year.

**Total organ dose**
The sum of the equivalent dose to the whole body for external exposures and the committed equivalent dose to any organ or tissue other than the skin or the lens of the eye.

**Transient individual**
An individual who is monitored at more than one DOE site during the calendar year.

**Urinalysis**
The technique of determining the amount of radioactive material in the urine excreted from the body.

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# References



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6. REMS Reporting Guide, issued February 23, 2012. Online at https://www.energy.gov/ehss/downloads/radiation-exposure-monitoring-systems-data-reporting-guide.

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8. DOE Standard, DOE-STD-1098-2017, "Radiological Control," January 2017. Online at https://www.standards.doe.gov/standards-documents/1000/1098-AStd-2017/@@images/file.

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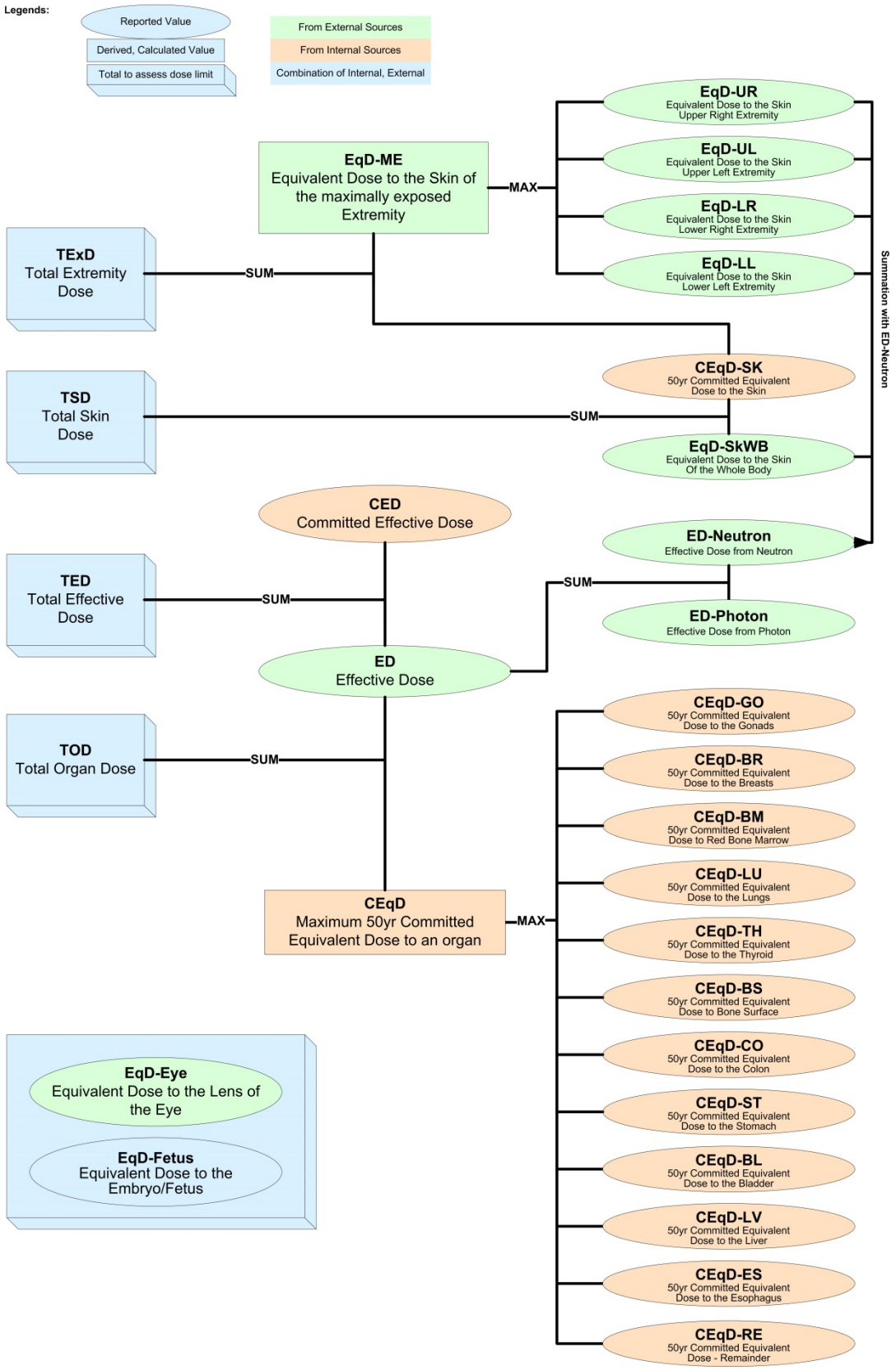
# DOE Radiation Exposure Monitoring System (REMS)
## *Dose Abbreviations, Definitions, and Relationships*



## DOE Occupational Radiation Exposure Report User Survey

DOE, striving to meet the needs of its stakeholders, is looking for suggestions on ways to improve the *DOE 2017 Occupational Radiation Exposure Report*. **Your feedback is important**. Constructive feedback will ensure the report can continue to meet user needs. Please fill out the attached survey form and return it to:

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Questions concerning this survey should be directed to Ms. Rao at (301) 903-2297.

1. Identification:

   Name: _____

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   2.1 Do you wish to remain on the distribution for the report? _____ yes _____ no

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| | Not Useful | | | | Very Useful |
|---|---|---|---|---|---|
| Please rate the usefulness of this report overall: | 1 | 2 | 3 | 4 | 5 |

Please rate the usefulness of the analysis presented in the following sections:

| | | | | | |
|---|---|---|---|---|---|
| Executive Summary | 1 | 2 | 3 | 4 | 5 |
| Analysis of Aggregate Data | 1 | 2 | 3 | 4 | 5 |
| Collective Dose | 1 | 2 | 3 | 4 | 5 |
| Average Measurable Dose | 1 | 2 | 3 | 4 | 5 |
| Dose Distribution | 1 | 2 | 3 | 4 | 5 |
| Analysis of Individual Dose Data | 1 | 2 | 3 | 4 | 5 |
| Doses in Excess of DOE limit (5 rem) | 1 | 2 | 3 | 4 | 5 |
| Doses in Excess of ACL limit (2 rem) | 1 | 2 | 3 | 4 | 5 |
| Intakes of Radioactive Material | 1 | 2 | 3 | 4 | 5 |
| Bioassay and Intake Summary Information | 1 | 2 | 3 | 4 | 5 |
| Analysis of Site Data | 1 | 2 | 3 | 4 | 5 |
| Collective TED by Site and Other Facilities | 1 | 2 | 3 | 4 | 5 |
| Activities Significantly Contributing to Collective Dose | 1 | 2 | 3 | 4 | 5 |
| Additional Site Descriptions | 1 | 2 | 3 | 4 | 5 |
| Summary by Program Office | 1 | 2 | 3 | 4 | 5 |
| Transient Individuals | 1 | 2 | 3 | 4 | 5 |
| Historical Data | 1 | 2 | 3 | 4 | 5 |
| DOE Occupational Dose in Relation to Other Activities | 1 | 2 | 3 | 4 | 5 |
| ALARA Activities at DOE | 1 | 2 | 3 | 4 | 5 |
| Conclusions | 1 | 2 | 3 | 4 | 5 |

Please rate the importance of the timeliness of the publication of this report as it relates to your professional need for the information on occupational radiation exposure at DOE:

| Not important | | | | Critical |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

Please provide any additional input or comments on the report.

**Prepared for the Office of Environment, Health, Safety and Security**
**by ORAU, P.O. Box 117 • Oak Ridge, TN 37831-0117**