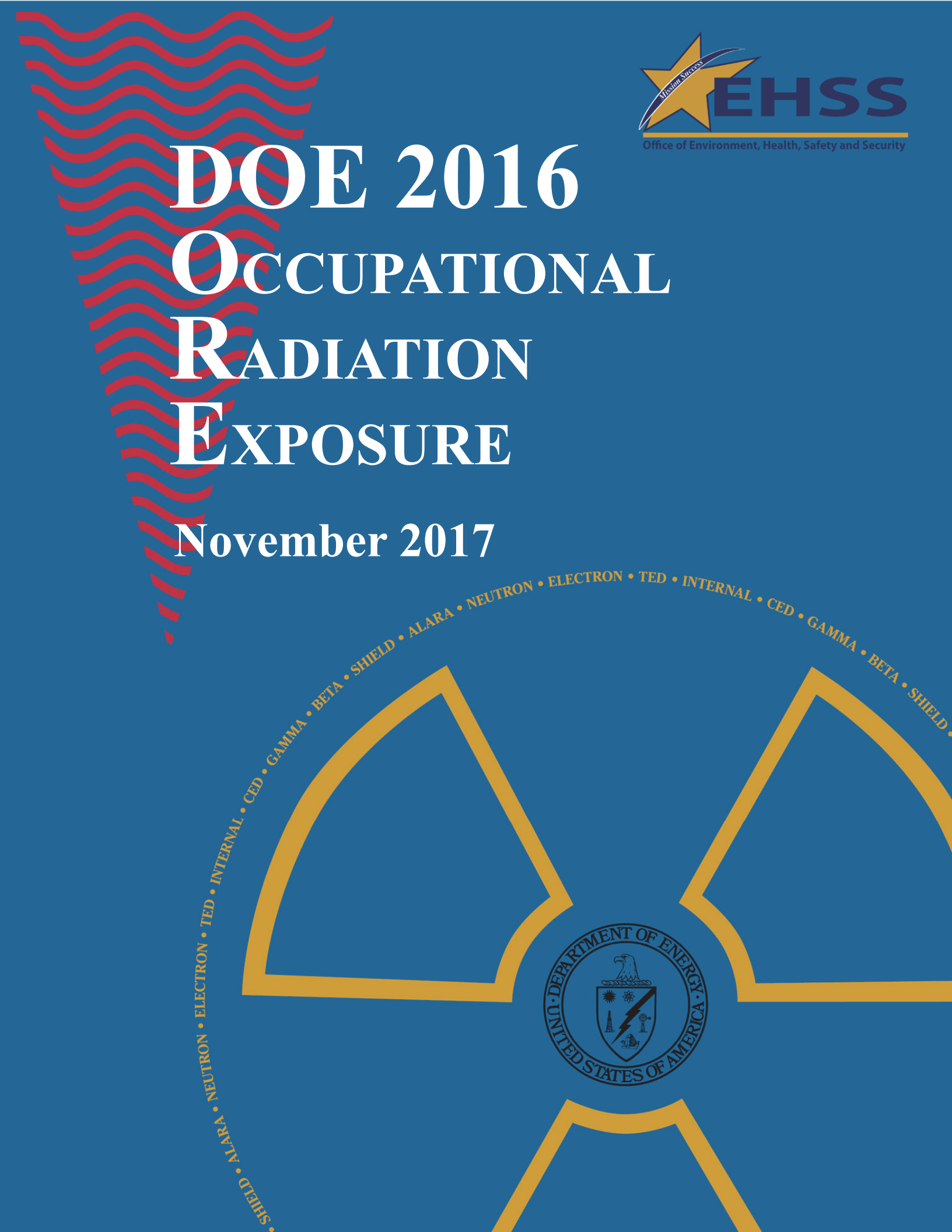
Office of Environment, Health, Safety and Security

DOE 2016 Occupational Radiation Exposure

November 2017



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 2016 Occupational Radiation Exposure

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Office of Environment, Health, Safety and Security

Foreword

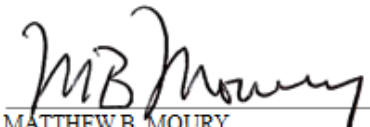
The Department of Energy (DOE) *2016 Occupational Radiation Exposure Report* presents the results of analyses of occupational radiation exposures at DOE facilities during 2016. This report includes occupational radiation exposure information for all DOE employees, contractors, and subcontractors, as 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 Environment, Health, Safety and Security (AU) evaluation and analysis which inform management and stakeholders of the continued vigilance and success of the DOE sites in minimizing radiation exposure to workers.

The U.S. Department of Energy (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 AU Office of Environment, Safety, & Health (ES&H) Reporting and Analysis collects, analyzes, and disseminates data and performance indicators, such as occupational radiation exposure information, to support this mission.

The safety focus for DOE are to maintain radiation exposures below the administrative control levels (ACLs) and the DOE radiation dose limits, and to further reduce exposure through the as low as reasonably achievable (ALARA) process. The *DOE 2016 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, researchers, and national and international agencies involved in developing policies to protect workers and members of the public from the harmful effects of radiation.

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
ACRR	Annular Core Research Reactor
AHCF	Auxiliary Hot Cell Facility
ALARA	As Low As Reasonably Achievable
AMWTP	Advanced Mixed Waste Treatment Project
ANL	Argonne National Laboratory
ATR	Advanced Test Reactor
AU	Office of Environment, Health, Safety and Security
BNL	Brookhaven National Laboratory
CED	Committed Effective Dose
CEDE	Committed Effective Dose Equivalent
CEqD	Committed Equivalent Dose
CFI	Center for Functional Imaging
CFR	Code of Federal Regulations
CRM	Certified Reference Materials
D&D	Decontamination and Decommissioning
DOE	U.S. Department of Energy
DTRA	Defense Threat Reduction Agency
DUF_6	Depleted Uranium Hexafluoride
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
ES&H	Environment, Safety, & Health
ETEC	Energy Technology Engineering Center
ETTP	East Tennessee Technology Park
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
LCLS	LINAC Coherent Light Source
LEP	Life Extension Program
LINAC	Linear Accelerator
LLNL	Lawrence Livermore National Laboratory
mSv	Millisievert
NBL	New Brunswick Laboratory
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
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
ORP	Office of River Protection
OST	Office of Secure Transportation
PDF	Portable Document Format
PGDP	Paducah Gaseous Diffusion Plant
PNNL	Pacific Northwest National Laboratory
PORTS	Portsmouth Gaseous Diffusion Plant
PPPL	Princeton Plasma Physics Laboratory
Pu-238	Plutonium-238
RCT	Radiation Control Technicians
rem	Roentgen equivalent man
REMS	Radiation Exposure Monitoring System
RF	Radio Frequency
RH-TRU	Remote-Handled Transuranic
RPP	Argonne Radiation Protection Program
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
SRNS	Savannah River Nuclear Solutions
SRS	Savannah River Site
Sv	Sievert
TED	Total Effective Dose
TEqD	Total Equivalent Dose
TJNAF	Thomas Jefferson National Accelerator Facility
TREAT	Transient Reactor Test
TRU	Transuranic
TSS	Transportation Safeguards System
U	Uranium
U-234	Uranium-234
U-238	Uranium-238
UMTRA	Uranium Mill Tailings Remedial Action Project
USEC	United States Enrichment Corporation
WIPP	Waste Isolation Pilot Plant
WVDP	West Valley Demonstration Project
Y-12	Y-12 National Security Complex

Executive Summary

The DOE Office of Environment, Safety, and Health (ES&H) Reporting and Analysis (AU-23) within the Office of 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 2016 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 2016. 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 overall amount of radiation dose received during the conduct of operations at DOE is represented by collective dose (aggregate data). The collective dose is the sum of the doses received by all individuals with a measurable dose and is measured in units of person-roentgen equivalent in man (person-rem) and person-mSv. In this report, dose refers to the Total Effective Dose (TED), which is the summation of the TED reported for all monitored individuals. The TED is the effective dose from external sources, which includes neutron, photon and energetic beta radiation, and the internal committed effective dose (CED), which results from the intake of radioactive material into the body. The total DOE collective TED decreased by 5 percent from 2015 to 2016, as shown in *Exhibit ES-1*, due to decreases in 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 20 percent from 2015 to 2016, as shown in *Exhibit ES-2*.

Exhibit ES-1:
Collective TED (person-rem), 2012–2016.

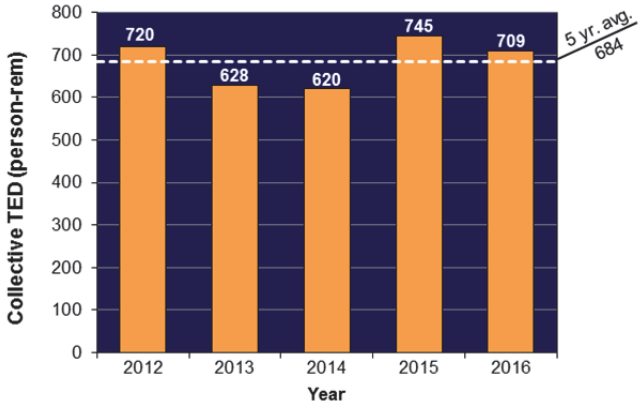
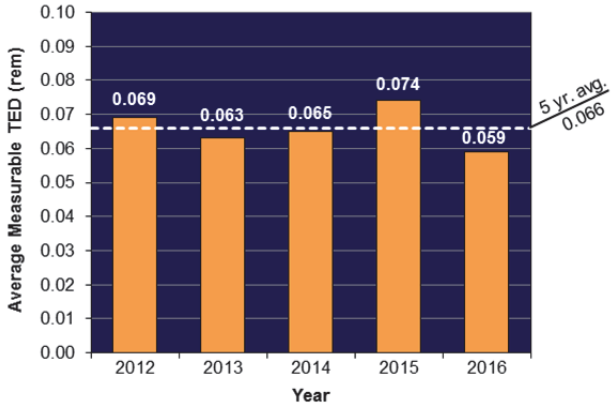


Exhibit ES-2:
Average Measurable TED (rem), 2012–2016.



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 2016.
- The collective TED decreased 5 percent from 745 person-rem (7,450 person-mSv) in 2015 to 709 person-rem (7,090 person-mSv) in 2016.
- The sites contributing the majority of the collective TED were (in descending order): Oak Ridge (OR), Savannah River Site (SRS), Los Alamos National Laboratory (LANL), Idaho, and Hanford. These sites accounted for 75 percent of the collective TED in 2016. The collective TED increased at Oak Ridge and SRS. The increase at Oak Ridge National Laboratory (ORNL) was due largely to increased work activities. The collective TED decreased at LANL, Idaho and Hanford due to improved work processes and reduced operations.
- The collective CED (internal exposure) increased by 19 percent from 51.7 person-rem (517 person-mSv) in 2015 to 61.5 person-rem (615 person-mSv) in 2016, as a result of increases in internal doses across the DOE complex, including 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) increased by 9 percent from 21.6 person-rem (216 person-mSv) in 2015 to 23.5 person-rem (235 person-mSv) in 2016.

Over the past 5 years, all monitored individuals received measurable TED below the 2 rem (20 mSv) TED ACL, which is well below the DOE regulatory limit of 5 rem (50 mSv) TED annually. The occupational radiation exposure records show that in 2016, 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:

http://energy.gov/ehss/occupational radiation exposure

Section One
Introduction

1 Introduction

The Department of Energy *(DOE) 2016 Occupational Radiation Exposure Report* presents the results of analyses of occupational radiation exposures at DOE facilities during 2016. 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 102 DOE organizations submitting radiation exposure reports for 2016 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, and additional items are available on the DOE web: http://energy.gov/ehss/occupational-radiation-exposure) and as appendices to this report.

1.2 Report Availability

This report is available online and may be downloaded from:

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

Requests for additional copies of this report, 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 REMS web site for more information on occupational radiation exposure, such as the following:

- Annual occupational radiation exposure reports in portable document format (PDF) since 1974;
- Guidance on reporting radiation exposure information to the DOE Headquarters Radiation Exposure Monitoring System (REMS);
- New, improved 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.

Section 1	Describes the content and organization of this report.
Section 2	Discusses the radiation protection and dose reporting requirements.
Section 3	Presents the 2016 occupational radiation dose data along with trends over the past 5 years.
Section 4	Provides instructions to submit successful ALARA projects. A detailed ALARA Activity summary is provided on the DOE Radiation Exposure web site once the final report is published. Please visit **http://energy.gov/ehss/occupational-radiation-exposure** and select Annual Reports to review.
Section 5	Discusses conclusions.
Appendices	The appendices are offered on the DOE Radiation Exposure web site once the final report is published. Please visit **http://energy.gov/ehss/occupational-radiation-exposure** and select Annual Reports to review. The appendices provide a comprehensive breakdown of dose by field office and site, as well as distributions by facility type and occupation, type of dose, and internal dose by radionuclide.

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Standards and Requirements

One of DOE's primary objectives is to provide a safe and healthy workplace for all employees and contractors. To meet this objective, the DOE Office of Environment, Health, Safety and Security (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 the radiation protection standards and requirements for 2016. 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 total effective dose 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. DOE Manual 231.1-1A, *Environment, Safety, and Health Reporting Manual*, has been cancelled. Specific instructions for preparing occupational exposure data for submittal to the REMS repository are contained in the REMS Reporting Guide available online at: http://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 Amended 11/4/98 Amended 6/8/07 Amended 4/13/11	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 and EqD to the maximally exposed extremity + CEqD-SK	50 rem
Declared pregnant workers*	835.206	Total equivalent dose	TEqD	0.500 rem per gestation period
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.

Occupational Radiation Dose at DOE

3.1 Analysis of the Data

Key indicators are useful when evaluating occupational radiation exposures received at DOE facilities. The key indicators are analyzed to identify and correlate parameters that impact radiation 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.

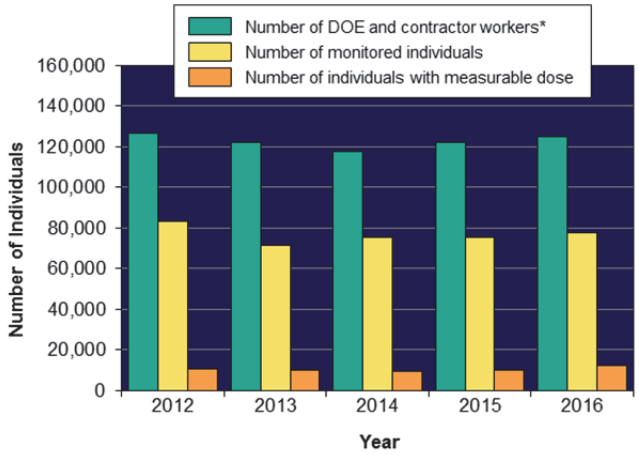
3.2.2 Number of Individuals with Measurable Dose

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, all monitored individuals received measurable total effective dose (TED) below the 2 rem (20 mSv) TED ACL, which is well below the DOE regulatory limit of 5 rem (50 mSv) TED annually.

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, 2012–2016.



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

For 2016, 62% of the DOE workforce was monitored for radiation dose, and 15% of monitored individuals received a measurable dose.

Exhibit 3-1b:
Monitoring of the DOE Workforce, 2012–2016.

Year	DOE & Contractor Workforce	Number of Monitored Individuals	Percent of Monitored Individuals*	Number of Individuals w/Measurable Dose	Percent of Individuals with Measurable Dose*
2012	126,776	83,043	66% ▼	10,461	13% ▼
2013	122,159	71,582	59% ▼	9,903	14% ▲
2014	117,727	75,447	64% ▲	9,501	13% ▼
2015	122,163	75,557	62% ▼	10,024	13%
2016	125,181	77,836	62%	12,005	15% ▲
5-Year Average	**122,801**	**76,693**	**62%**	**10,379**	**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

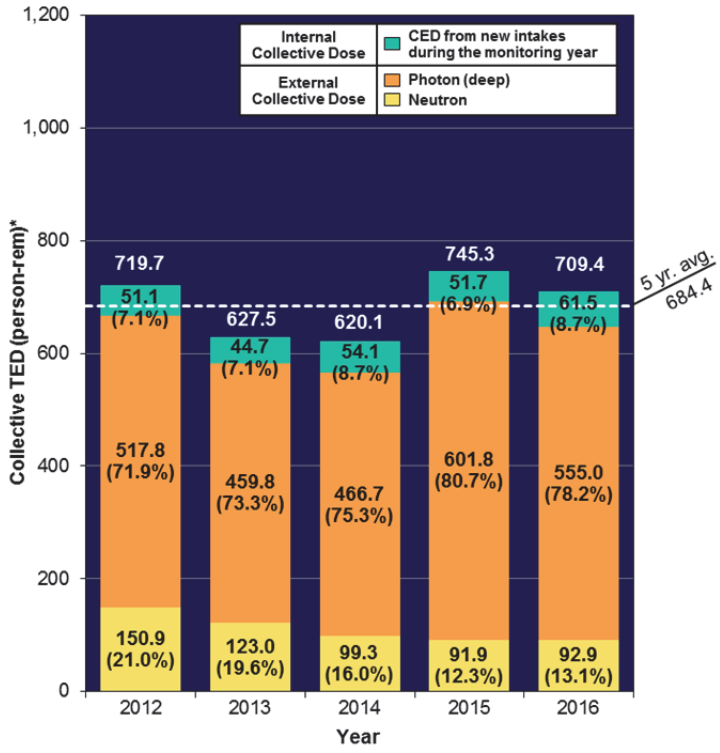
The collective dose is the sum of the dose received by all individuals with a measurable dose and is measured in units of person-rem and person-mSv. DOE monitors the collective dose as one measure of the overall performance of radiation protection programs to keep individual exposures and collective 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 decreased at DOE by 5 percent from 745.3 person-rem (7,453 person-mSv) in 2015 to 709.4 person-rem (7,094 person-mSv) in 2016.

The internal dose is based on the 50-year committed effective dose (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 3-2:
Components of TED, 2012–2016



The collective TED decreased by 5% at DOE from 2015 to 2016.

The collective internal dose increased by 19% from 2015 to 2016.

The collective neutron dose increased by 1% from 2015 to 2016.

The collective photon dose decreased by 8% from 2015 to 2016.

Effective Dose from photons—the component of external dose from gamma or X-ray electromagnetic radiation (also includes energetic betas)

Effective dose from neutrons the component of external dose from neutrons ejected from the nucleus of an atom during nuclear reactions

Internal dose—radiation dose resulting from radioactive material taken into the body

* 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 19 percent from 51.7 person-rem (517 person-mSv) in 2015 to 61.5 person-rem (615 person-mSv) in 2016, due to increases in internal doses across the DOE complex including the Y-12 National Security Complex (Y-12). The collective photon dose decreased by 8 percent from 601.8 person-rem (6,018 person-mSv) in 2015 to 555.0 person-rem (5,550 person-mSv) in 2016.

The neutron component of the collective TED increased by 1 percent from 91.9 person-rem (919 person-mSv) in 2015 to 92.9 person-rem (929 person-mSv) in 2016. The increase resulted primarily from increases in collective neutron dose at Oak Ridge National Laboratory (ORNL) (38 percent), and SRS (48 percent).

The five sites that contributed most (75 percent) of the DOE collective TED in 2016 were (in descending order of collective TED): Oak Ridge—20 percent (including East Tennessee Technology Park [ETTP], Y-12, ORNL, and Oak Ridge Institute for Science and Education [ORISE]); SRS—16 percent; Los Alamos National Laboratory (LANL)—13 percent; Idaho Site—13 percent (including Advanced Mixed Waste Treatment Project [AMWTP], Idaho Cleanup Project [ICP], and Idaho National Laboratory [INL]); and Hanford—13 percent (including the Hanford Site, Pacific Northwest National Laboratory [PNNL], and Office of River Protection [ORP]).

Idaho, Hanford, and LANL had decreases in collective TED in 2016 compared with 2015 (25 percent, 21 percent and 2 percent, respectively). The other two top contributors reported increases in collective TED. In descending order of the percent increase in collective TED are Oak Ridge (21 percent higher) and SRS (17 percent higher). (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 20 percent from 0.074 rem (0.740 mSv) in 2015 to 0.059 rem (0.590 mSv) in 2016. 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 dose (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 3-3:
Average Measurable TED, 2012–2016.

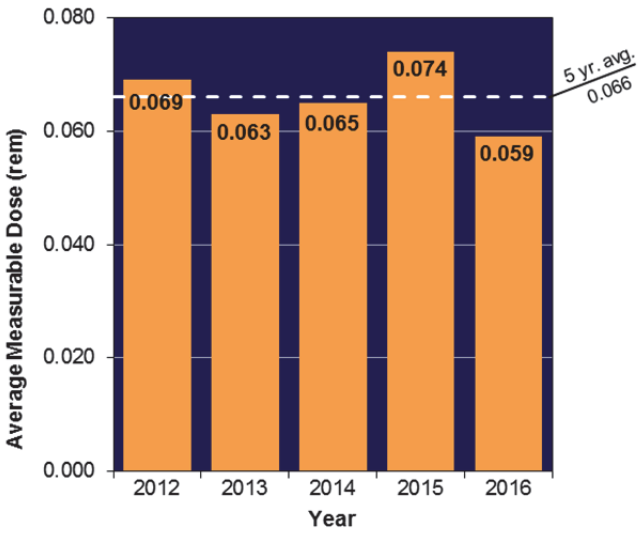


Exhibit 3-4 shows that the dose (TED) distribution for 2016 was higher in the less than measurable and measurable to 0.100 ranges compared with the 2015 data. Ninety-nine percent of all individuals monitored had doses less than 0.250 rem (2.5 mSv). Of those individuals with measurable dose, *Exhibit 3-5* presents the dose distribution in terms of the percentage of individuals with measurable TED in each range. Eighty percent of monitored individuals receive doses below the required monitoring threshold of 0.100 rem (1mSv) specified in 10 CFR 835.402 (a) and (c).

Exhibit 3-4:
Distribution of TED by Dose Range, 2012–2016.

	TED Range (rem)	2012	2013	2014	2015	2016
Number of Individuals in Each Dose Range*	Less than measurable	72,582	61,679	65,946	65,533	65,831
	Measurable to 0.100	8,443	8,151	7,707	8,022	10,159
	0.100–0.250	1,360	1,246	1,257	1,341	1,247
	0.250–0.500	528	421	444	448	451
	0.500–0.750	87	48	72	123	90
	0.750–1.000	27	28	15	49	38
	1.0–2.0	16	9	6	41	20
	2.0–3.0					
	3.0–4.0					
	4.0–5.0					
	>5.0					
Total number of records for monitored individuals		83,043	71,582	75,447	75,557	77,836
Number with measurable dose		10,461	9,903	9,501	10,024	12,005
Number with dose >0.100 rem		2,018	1,752	1,794	2,002	1,846
Collective TED (person-rem)		719.749	627.523	620.103	745.335	709.397
Average measurable TED (rem)		0.069	0.063	0.065	0.074	0.059

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

Exhibit 3-5:
Percentage of Individuals with Measurable TED by Dose Range, 2012–2016.

	TED Range (rem)	2012	2013	2014	2015	2016
Percentage of Individuals with Measurable TED*	Measurable <0.100	80.71%	82.31%	81.12%	80.03%	84.62%
	0.100–0.250	13.00%	12.58%	13.23%	13.38%	10.39%
	0.250–0.500	5.05%	4.25%	4.67%	4.47%	3.76%
	0.500–0.750	0.83%	0.48%	0.76%	1.23%	0.75%
	0.750–1.000	0.26%	0.28%	0.16%	0.49%	0.32%
	1.0–2.0	0.15%	0.09%	0.06%	0.41%	0.17%
	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		**13%**	**14%**	**13%**	**13%**	**15%**
% of monitored individuals with dose > 0.100 rem		**2%**	**2%**	**2%**	**3%**	**2%**

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

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.

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 2012 through 2016.

3.3.2 Doses in Excess of Administrative Control Level

The DOE Standard Radiological Control (DOE-STD-1098-2017) [8] 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 2012 through 2016.

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 process.

Exhibit 3-6 shows the number of individuals with measurable CED, collective CED, and average measurable CED for 2012 to 2016. The number of individuals with measurable CED increased by 8 percent from 1,147 in 2015 to 1,241 in 2016, while the collective CED increased by 19 percent. The average measurable CED increased from 0.045 rem (0.450 mSv) in 2015 to 0.050 rem (0.500 mSv) in 2016 and was slightly above the 5-year average measurable CED.

Ninety-nine percent of the collective CED in 2016 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 internal dose (CED) from 2012 to 2016. The total number of individuals with measurable CED in each dose range is the sum of the number of individuals receiving an internal dose (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 3-6:
Number of Individuals with Measurable CED, Collective CED, and Average Measurable CED, 2012–2016.

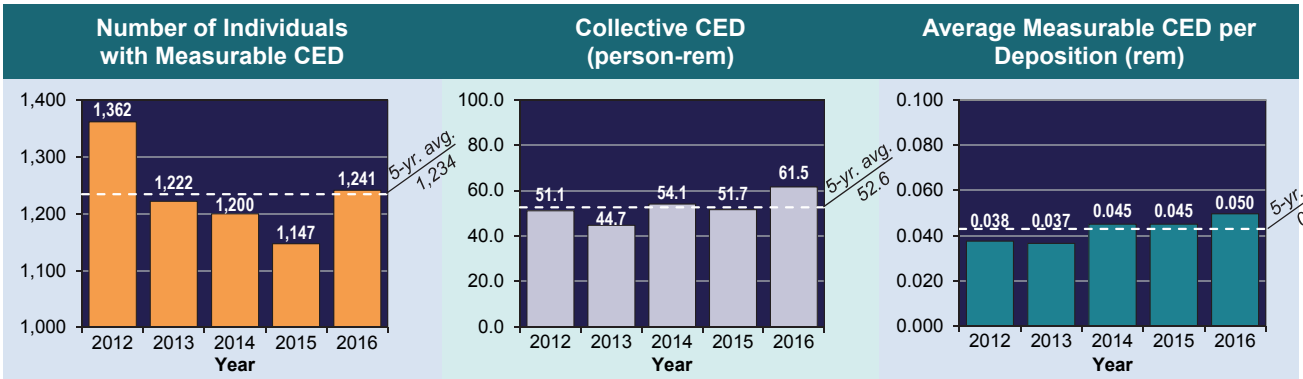


Exhibit 3-7:
Internal Dose Distribution from Intakes, 2012–2016.

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		
2012	737	481	125	17	1	1						1362	51.099
2013	668	439	107	5	2	1						1,222	44.687
2014	565	479	140	14	2							1,200	54.082
2015	540	466	117	23	1							1,147	51.666
2016	546	522	135	36	2							1,241	61.544

* 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 2016, 44 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 12 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].

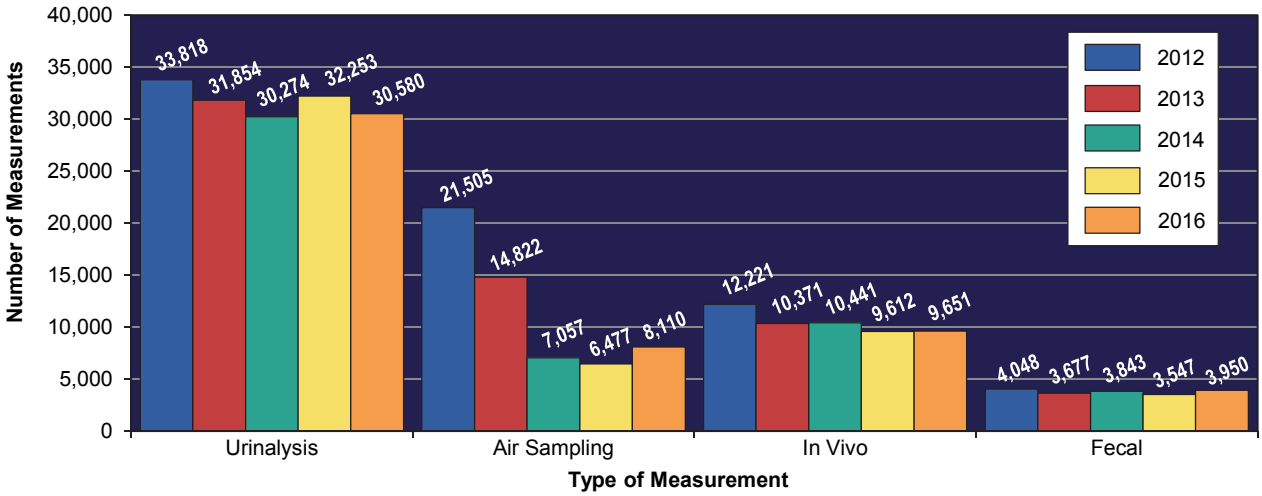
3.3.4 Bioassay and Intake Summary Information

For the monitoring year 2016, 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 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 52 percent of the "In Vivo" measurements.

The measurements reported as "Air Sampling" 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 16 percent of the total measurements. The Nevada National Security Site (NNSS) had the largest percentage increase (1,184 percent) in the number of "Urinalysis" measurements in 2016 and the largest percentage increase (272 percent) in the number of "Air Sampling" measurements (see section 3.4.4 for additional information).

Sixty-eight percent of the "Urinalysis" measurements in 2016 were performed at four sites: Y-12, LANL, SRS, and the Paducah Gaseous Diffusion Plant (PGDP).

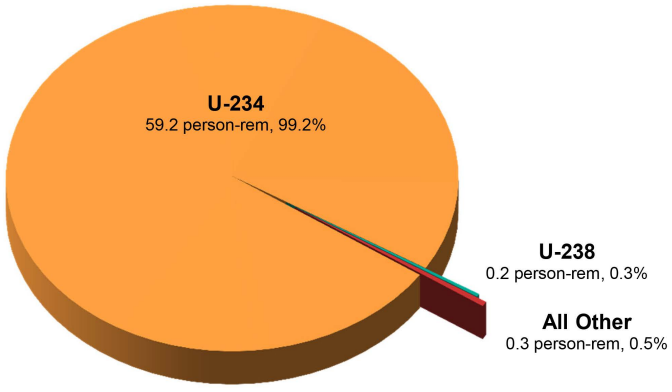
Exhibit 3-8:
Bioassay and Air Sampling Measurements, 2012–2016.



Y-12 performed the largest number of bioassay measurements overall, comprising 23 percent of the total measurements taken.

Exhibit 3-9 shows the breakdown of the collective CED by radionuclide for 2016. 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 CED per radionuclide for *Exhibit 3-9*, which is based on intake summaries, does not equal the collective CED found in *Exhibit 3-7*, which is based on individual dose records.

Exhibit 3-9:
Collective CED by Radionuclide from Internal Exposure, 2016.



The annual REMS appendices are located at http://energy.gov/ehss/listings/annual-doe-occupational-radiation-exposure-reports, within each annual report. *Exhibits B-4*, Internal Dose by Site; *B-17*, Internal Dose by Facility Type and Nuclide; *B-19*, Internal Dose by Labor Category; and *B-21*, 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 2014 through 2016 for the major DOE sites and operations/field offices are shown graphically in *Exhibit 3-10*. A list of the collective TED and number of individuals with measurable TED by DOE sites is shown in *Exhibit 3-11*. The collective TED decreased 5 percent from 745 person-rem (7,450 person-mSv) in 2015 to 709 person-rem (7,090 person-mSv) in 2016, with Oak Ridge (including ETTP, Y-12, ORNL, and ORISE); SRS; LANL; Idaho (including INL, ICP, and AMWTP); and Hanford (including the Hanford Site, PNNL, and ORP) contributing 75 percent of the total DOE collective TED.

3.4.2 Changes by Site from 2015 to 2016

Exhibit 3-12 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.

Exhibit 3-10:
Collective TED by DOE Site for 2014–2016.

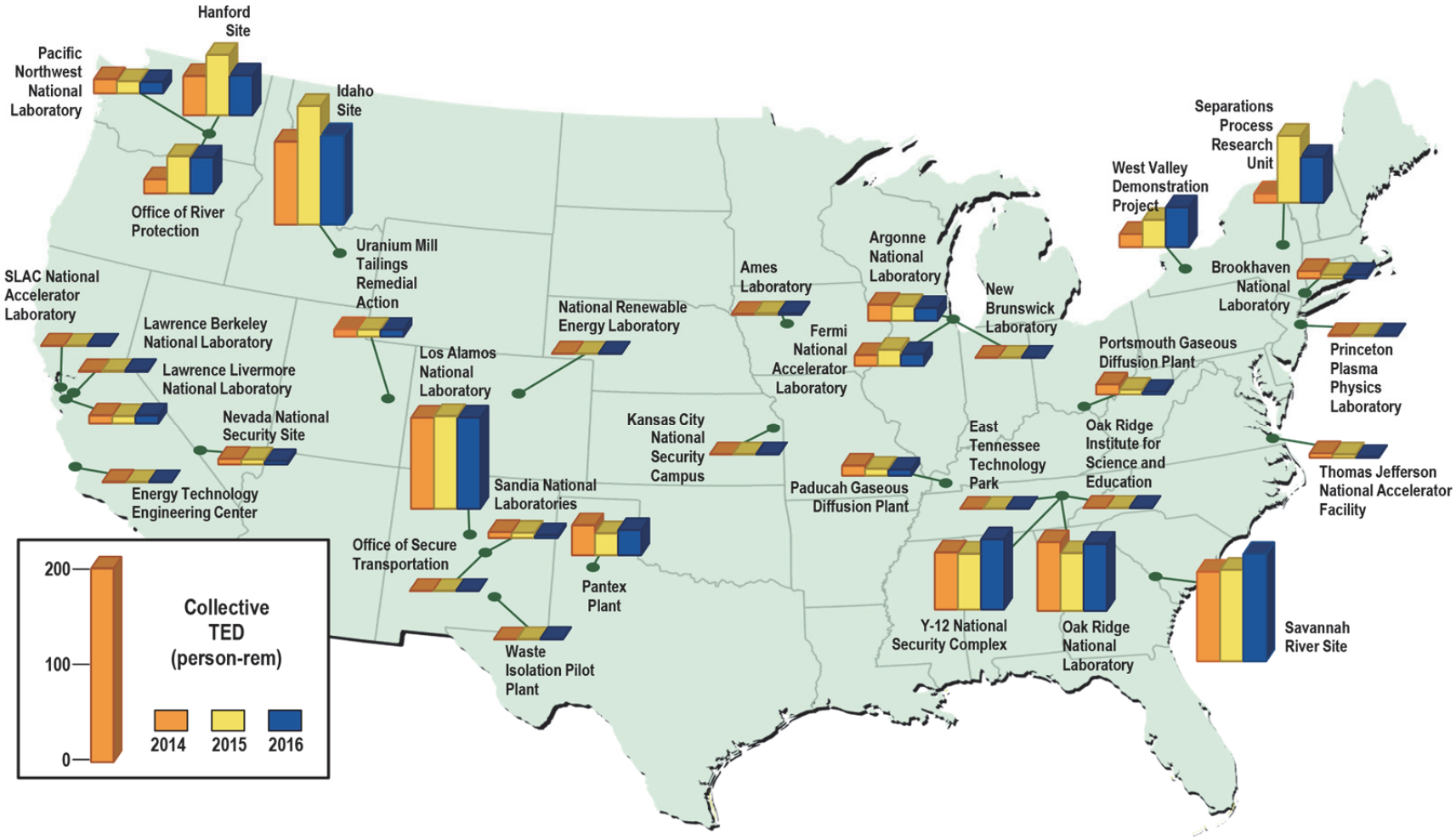


Exhibit 3-11:
Collective TED and Number of Individuals with Measurable TED by DOE Site, 2014–2016.

Site	2014		2015		2016	
	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	0.873	33	1.247	39	1.240	41
Argonne National Laboratory	16.492	84	14.818	83	13.080	70
Brookhaven National Laboratory	7.282	129	3.345	134	3.217	84
Energy Technology Engineering Center	0.489	69	0.068	3	0.089	2
Fermi National Accelerator Laboratory	11.070	193	16.640	235	11.930	232
Hanford:						
Hanford Site	40.715	659	62.612	687	41.109	1,218
Office of River Protection	14.653	412	38.608	648	37.391	944
Pacific Northwest National Laboratory	14.634	479	12.581	461	11.599	420
Hanford Totals:	*70.002*	*1,550*	*113.801*	*1,796*	*90.099*	*2,582*
Idaho Site	86.202	1,174	**123.232**	1,331	92.670	1,273
Kansas City National Security Campus	0.022	11	0.020	12	0.063	24
Lawrence Berkeley National Laboratory	0.463	8	0.796	11	0.823	13
Lawrence Livermore National Laboratory	8.353	108	7.573	105	8.215	98
Los Alamos National Laboratory	**95.436**	1,401	97.209	1,135	95.565	1,106
National Renewable Energy Laboratory	0.107	7	0.028	4	0.034	7
Nevada National Security Site	5.638	116	5.045	98	3.295	84
New Brunswick Laboratory	0.023	2			0.096	4
Oak Ridge:						
East Tennessee Technology Park	0.004	1	0.059	4	0.114	3
Oak Ridge Institute for Science and Education	0.210	23	0.122	10	0.171	9
Oak Ridge National Laboratory	71.304	618	59.959	598	69.551	618
Y-12 National Security Complex	59.296	1,326	58.010	1,201	72.807	1,460
Oak Ridge Totals:	*130.814*	*1,968*	*118.150*	*1,813*	*142.643*	*2,090*
Office of Secure Transportation	0.090	5	0.029	2	0.072	3
Paducah Gaseous Diffusion Plant	10.306	139	7.058	337	6.201	559
Pantex Plant	31.084	305	22.618	301	25.918	295
Portsmouth Gaseous Diffusion Plant	10.302	95	4.716	59	2.509	40
Princeton Plasma Physics Laboratory	0.693	123	0.623	126	0.311	78
Sandia National Laboratories	5.982	88	5.284	99	2.756	68
Savannah River Site	93.027	**1,584**	94.871	**1,882**	**111.338**	**2,799**
Separations Process Research Unit	9.338	76	69.291	149	47.541	101
SLAC National Accelerator Laboratory	0.246	9	0.069	2	0.170	6
Thomas Jefferson National Accelerator Facility	4.452	42	3.348	47	0.777	30
Uranium Mill Tailings Remedial Action Project	7.756	61	7.177	86	7.044	131
Waste Isolation Pilot Plant	0.034	3	0.161	12	0.311	22
West Valley Demonstration Project	13.424	112	28.107	122	41.122	147
Service Center Personnel*	0.103	6	0.011	1	0.268	16
Totals	**620.103**	**9,501**	**745.335**	**10,024**	**709.397**	**12,005**

Note: Bold and boxed values indicate the greatest value in each column.
* 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.

Exhibit 3-12:
Site Dose Data, 2016.

Site	2016					
	Collective TED (person-rem)	Percent Change from 2015	Number with Meas. TED	Percent Change from 2015	Avg. Meas. TED (person-rem)	Percent Change from 2015
Ames Laboratory	1.240	-1% ▼	41	5% ▲	0.030	-5% ▼
Argonne National Laboratory	13.080	-12% ▼	70	-16% ▼	0.187	5% ▲
Brookhaven National Laboratory	3.217	-4% ▼	84	-37% ▼	0.038	**53%** ▲
Energy Technology Engineering Center	0.089	◊	2	◊	0.045	◊
Fermi National Accelerator Laboratory	11.930	-28% ▼	232	-1% ▼	0.051	-27% ▼
Hanford:						
Hanford Site	41.109	-34% ▼	1,218	**77%** ▲	0.034	-63% ▼
Office of River Protection	37.391	-3% ▼	944	46% ▲	0.040	-34% ▼
Pacific Northwest National Laboratory	11.599	-8% ▼	420	-9% ▼	0.028	1% ▲
Hanford Totals:	*90.099*	*-21%* ▼	*2,582*	*44%* ▲	*0.035*	*-45%* ▼
Idaho Site	92.670	-25% ▼	1,273	-4% ▼	0.073	-21% ▼
Kansas City National Security Campus	0.063	◊	24	◊	0.003	◊
Lawrence Berkeley National Laboratory	0.823	◊	13	◊	0.063	◊
Lawrence Livermore National Laboratory	8.215	8% ▲	98	-7% ▼	0.084	16% ▲
Los Alamos National Laboratory	95.565	-2% ▼	1,106	-3% ▼	0.086	1% ▲
National Renewable Energy Laboratory	0.034	◊	7	◊	0.005	◊
Nevada National Security Site	3.295	-35% ▼	84	-14% ▼	0.039	-24% ▼
New Brunswick Laboratory	0.096	◊	4	◊	0.024	◊
Oak Ridge:						
East Tennessee Technology Park	0.114	◊	3	◊	0.038	◊
Oak Ridge Institute for Science and Education	0.171	◊	9	◊	0.019	◊
Oak Ridge National Laboratory	69.551	16% ▲	618	3% ▲	0.113	12% ▲
Y-12 National Security Complex	72.807	26% ▲	1,460	22% ▲	0.050	3% ▲
Oak Ridge Totals:	*142.643*	*21%* ▲	*2,090*	*15%* ▲	*0.068*	*5%* ▲
Office of Secure Transportation	0.072	◊	3	◊	0.024	◊
Paducah Gaseous Diffusion Plant	6.201	-12% ▼	559	66% ▲	0.011	-47% ▼
Pantex Plant	25.918	15% ▲	295	-2% ▼	0.088	17% ▲
Portsmouth Gaseous Diffusion Plant	2.509	-47% ▼	40	-32% ▼	0.063	-22% ▼
Princeton Plasma Physics Laboratory	0.311	◊	78	◊	0.004	◊
Sandia National Laboratories	2.756	-48% ▼	68	-31% ▼	0.041	-24% ▼
Savannah River Site	**111.338**	17% ▲	**2,799**	49% ▲	0.040	-21% ▼
Separations Process Research Unit	47.541	-31% ▼	101	-32% ▼	**0.471**	1% ▲
SLAC National Accelerator Laboratory	0.170	◊	6	◊	0.028	◊
Thomas Jefferson National Accelerator Facility	0.777	◊	30	◊	0.026	◊
Uranium Mill Tailings Remedial Action Project	7.044	-2% ▼	131	52% ▲	0.054	-36% ▼
Waste Isolation Pilot Plant	0.311	◊	22	◊	0.014	◊
West Valley Demonstration Project	41.122	**46%** ▲	147	20% ▲	0.280	21% ▲
Service Center Personnel*	0.268	◊	16	◊	0.017	◊
Totals	**709.397**	**-5%** ▼	**12,005**	**20%** ▲	**0.059**	**-21%** ▼

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.

Changes that have the most impact in the overall values at DOE typically occur at sites with large collective TED. In 2016, the largest percentage of change was observed at the West Valley Demonstration Project (WVDP), which increased by 46 percent from 2015. (See section 3.4.4.)

Seventeen of the 34 DOE sites reported decreases in the collective TED from the 2015 values, and 17 of the 34 DOE sites reported increases in the collective TED from the 2015 values.

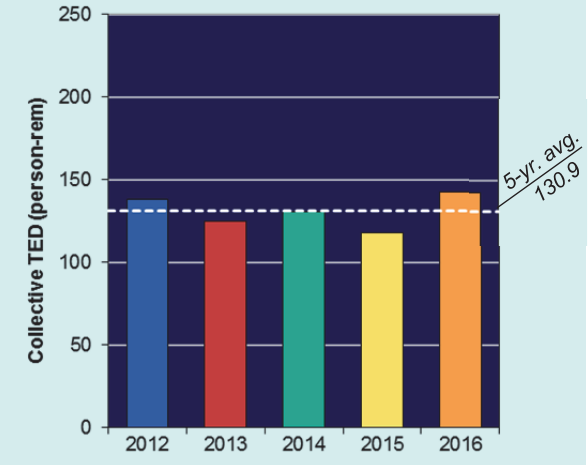
Seventeen of the 34 reporting sites experienced decreases in the number of workers with a measurable TED from 2015 to 2016. The largest decrease in total number of workers with a measurable TED occurred at Idaho with a decrease of 58 workers.

Seventeen of the 34 reporting sites experienced increases in the number of workers with a measurable TED from 2015 to 2016. The largest increase in the number of workers receiving a measurable TED occurred at Savannah River Site (SRS) with an increase of 917 workers. 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 2016

In an effort to identify the reasons for changes in the collective dose at DOE, all of the larger sites were contacted to provide information on activities that significantly contributed to the collective dose for 2016. These sites, presented in descending order of collective TED (Oak Ridge, SRS, LANL, Idaho, and Hanford), each had a collective TED over 90 person-rem (900 person-mSv) and were the top contributors to the collective TED in 2016. These sites comprised 75 percent of the total collective TED at DOE. Three sites reported decreases in the collective TED, which contributed to a 5 percent decrease in the DOE collective TED from 745 person-rem (7,450 person-mSv) in 2015 to 709 person-rem (7,090 person-mSv) in 2016. The sites significantly contributing to the collective TED in 2016 are shown in *Exhibit 3-13*, including a description of activities that affected the collective TED.

Exhibit 3-13:
Activities Significantly Contributing to Collective TED in 2016.

Oak Ridge	Percent Change for Last Year 2015 2016	Percent Change for Past 3 Years 2014 2016	Percent Change for Past 5 Years 2012 2016
	20.7% ▲	9.0% ▲	3.5% ▲

* Up arrows indicate an increase in change. Down arrows indicate a decrease in change.

Description of Activities at Oak Ridge

The 2016 collective TED at all Oak Ridge Sites was 142.643 person-rem (1,426.430 person-mSv), a 21 percent increase compared with 2015 (118.150 person-rem [1,181.500 person-mSv]).

Y-12 National Security Complex (Y-12)

During 2016, Y-12 reported monitoring 6,368 individuals and 1,460 individuals had measurable TED, a 22 percent increase from 2015 (see *Exhibit 3-12* for more details). The collective TED increased 26 percent from

Description of Activities at Oak Ridge (continued)

58.010 person-rem (580.100 person-mSv) in 2015 to 72.807 person-rem (728.070 person-mSv) in 2016. Possible contributing factors that affected the observed increases in the dose values were the increase in workload in 2016 as evidenced by radiological work permit use and a 10 percent increase in the overall number of individuals monitored.

The collective CED increased to 59.2 person-rem (592 person-mSv) in 2016 compared with 48.5 person-rem (485 person-mSv) in 2015.

No individual exceeded 2 rem (20 mSv) TED in 2016.

Oak Ridge National Laboratory (ORNL)

In 2016, ORNL reported monitoring 4,080 individuals, and 618 individuals received a measurable TED (see *Exhibit 3-12* for more details). This was a 3 percent increase in the number of individuals with measurable TED compared with 2015. The collective TED for ORNL in 2016 was 69.551 person-rem (695.510 person-mSv). This represents a 16 percent increase from 2015 (59.959 person-rem [599.590 person-mSv]). The increase in dose is primarily due to increased project work activities at hot cell and radiochemistry facilities in addition to increased maintenance and waste handling activities at neutron research and radiochemistry facilities.

No individual exceeded 2 rem (20 mSv) TED during 2016.

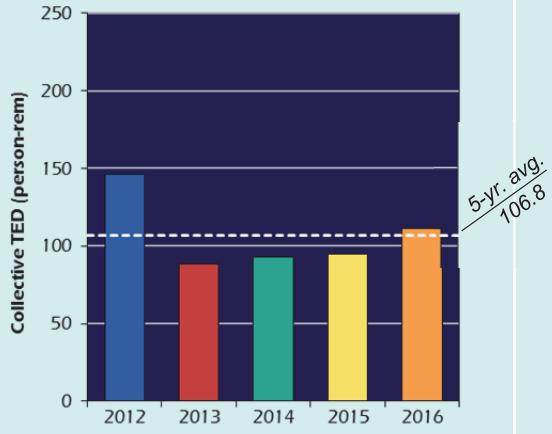
Oak Ridge Institute for Science and Education (ORISE)

In 2016, ORISE reported 102 individuals, which included 9 individuals with measurable dose (see *Exhibit 3-11* for more details). The collective TED for the 2016 monitoring year was 0.171 person-rem (1.710 person-mSv), an increase from 2015 (0.122 person-rem [1.220 person-mSv]). The dose increase was attributed to additional monitored individuals and work on projects resulting in higher doses.

East Tennessee Technology Park (ETTP)

In 2016, the DOE cleanup contractor monitored 356 individuals and 3 individuals had measurable TED (see *Exhibit 3-11* for more details). The 2016 collective TED was 0.114 person-rem (1.140 person-mSv), an increase from 2015 (0.059 person-rem [0.590 person-mSv]).

No individual exceeded 2 rem (20 mSv) TED in 2016.

Savannah River Site	Percent Change for Last Year 2015 2016	Percent Change for Past 3 Years 2014 2016	Percent Change for Past 5 Years 2012 2016
	17.4% ▲	19.7% ▲	-23.9% ▼

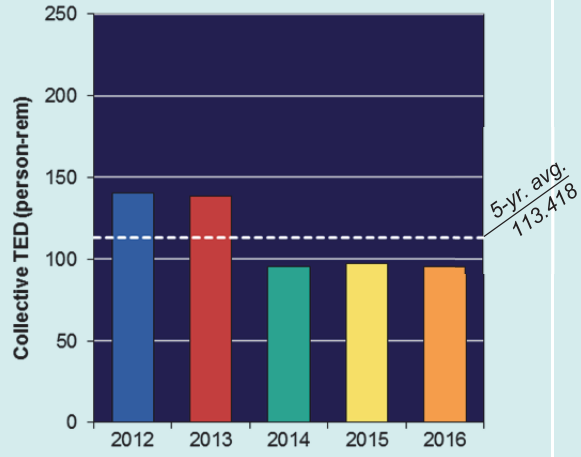
* Up arrows indicate an increase in change. Down arrows indicate a decrease in change.

Description of Activities at the Savannah River Site

The 2016 collective TED at Savannah River Site (SRS) was 111.338 person-rem (1,113.380 person-mSv). This was 17 percent higher than 2015 (94.871 person-rem [948.710 person-mSv]). The SRS collected records for 6,443 individuals in 2016, and 2,799 individuals had a measurable TED (see *Exhibit 3-12* for more details). The number of individuals with measurable TED increased by 49 percent from 2015 to 2016.

This increase was attributed to remediating a 1950s era underground liquid waste storage tank, completing the K Area complex battery change on the radio frequency tamper indicating device, beginning down-blend operations for plutonium for eventual storage at the Waste Isolation Pilot Plant (WIPP), and resuming process operations in portions of the H Canyon to allow for continued spent nuclear fuel dissolution. In addition, Savannah River Nuclear Solutions (SRNS) personnel began cleanup of the building used to produce fuel for the deep space missions such as the Galileo space probe to Jupiter.

No individual exceeded 2 rem (20 mSv) TED in 2016.

Los Alamos National Laboratory	Percent Change for Last Year 2015 2016	Percent Change for Past 3 Years 2014 2016	Percent Change for Past 5 Years 2012 2016
	-1.7% ▼	0.1% ▲	-31.8% ▼

* Up arrows indicate an increase in change. Down arrows indicate a decrease in change.

Description of Activities at Los Alamos National Laboratory

The 2016 collective TED at Los Alamos National Laboratory (LANL) was 95.565 person-rem (955.650 person-mSv). This was a 2 percent decrease from the previous year (97.209 person-rem [972.090 person-mSv]). LANL monitored 9,637 individuals, and of these, 1,106 had measurable TED, a 3 percent decrease from 2015 (see *Exhibit 3-12* for more details).

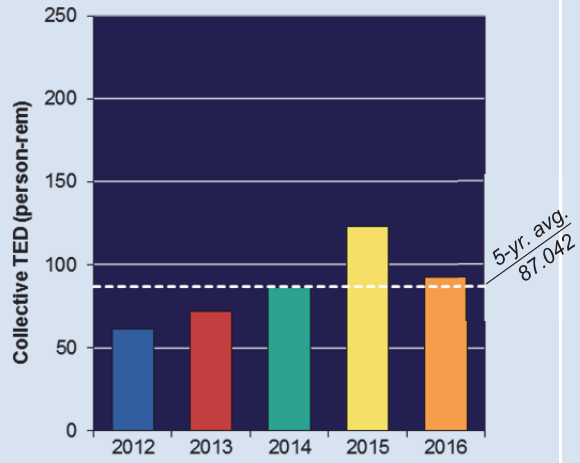
TA-55 plutonium facility operations accounted for the majority of occupational dose at LANL in 2016—historically consistent for LANL. Occupational dose was accrued from weapons manufacturing and related work, plutonium (Pu-238) work, repackaging materials, and providing radiation control technicians (RCT) and other infrastructure support for radiological work and facility maintenance at TA-55. The top 25 doses at LANL in 2016 were accrued at TA-55. A primary contributor to dose in 2016 was work with Pu-238, producing general purpose heat sources for use individually and in radioisotope thermoelectric generators. Doses at TA-55 would have been significantly higher in the balance of these areas; however, affected programmatic work was in the process of formal resumption following a work pause in 2013 associated with the criticality safety program.

Description of Activities at Los Alamos National Laboratory (continued)

In addition to TA-55 operations, a significant portion of LANL dose was accrued by workers commensurate with programmatic and maintenance work at the TA-53 Los Alamos Neutron Science Center.

Also, a portion of LANL dose was accrued by workers performing retrieval, repackaging, and shipping of radioactive solid waste within LANL facilities and at waste facilities TA-50 and TA-54. Work with solid waste was curtailed early in 2014 due to the contamination release event at WIPP and its association with LANL waste.

No individual received over 2 rem (20 mSv) TED at LANL during 2016.

Idaho Site	Percent Change for Last Year 2015 2016	Percent Change for Past 3 Years 2014 2016	Percent Change for Past 5 Years 2012 2016
	-24.8% ▼	7.5% ▲	51.2% ▲

* Up arrows indicate an increase in change. Down arrows indicate a decrease in change.

Description of Activities at the Idaho Site

The 2016 collective TED at Idaho was 92.670 person-rem (926.700 person-mSv), a 24.8 percent decrease compared with 123.232 person-rem (1,232.320 person-mSv) in 2015.

Idaho National Laboratory (INL)

In 2016, 4,310 individuals were monitored at INL; of these, 640 individuals had measurable TED—an 11 percent decrease from 2015. The collective TED was 36.541 person-rem (365.410 person-mSv) in 2016. This represents a decrease of 24 percent compared with 2015 (48.188 person-rem [481.880 person-mSv]).

The radiation exposure activities performed during 2016 at the INL Site included work at the Advanced Test Reactor (ATR) Complex, including experiment system operations, plant maintenance modifications, routine ATR power operations, routine ATR outage operations, and Research and Development Operations/Laboratory support.

In addition, activities at the Materials and Fuel Complex included maintenance at the analytical and radiochemistry laboratories, treatment and storage for waste repackaging, benchtop analysis activities at the Irradiated Materials Characterization Laboratory, and Zero Power Physics Reactor fuel handling. At the Central Facilities Area, Transient Reactor Test (TREAT) reactor, and Idaho Falls Facilities, training exercises increased for the Homeland Security/Defense Threat Reduction Agency (DTRA) and radiation instrument calibrations and health physics instrumentation laboratory work were conducted.

No individual exceeded 2 rem (20 mSv) TED in 2016.

Description of Activities at the Idaho Site (continued)

Idaho Cleanup Project (ICP)

Effective June 2016, ICP and Advanced Mixed Waste Treatment Project work were combined under a single new contractor. The DOE contractor at ICP submitted 2,003 records, which included 626 individuals with a measurable dose. The collective TED for 2016 was 56.005 person-rem (560.050 person-mSv).

The 2016 activities leading to radiation exposure included Waste Management remote-handled transuranic

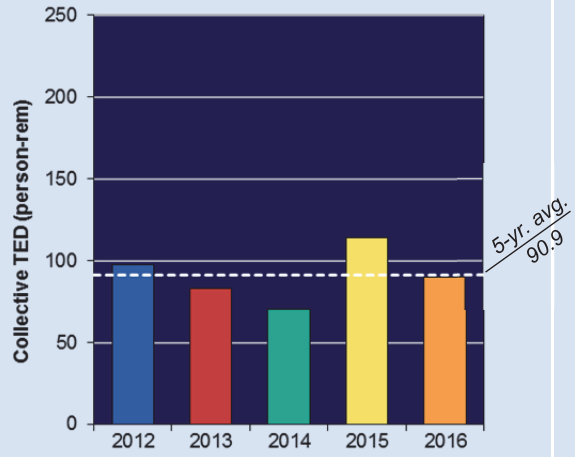
(RH-TRU) waste—repackaging, handling, and consolidation. Other activities included low-level waste shipments, macro encapsulation of mixed low-level waste, and decontamination activities. Activities at the Radioactive Waste Management Complex included continued retrieval operations, preventative maintenance on critical systems, and processing sludge drums. The main decrease in the annual collective dose was the reduction in hands-on cleaning of the knife gate valve and maintenance work on the Sodium Distillation System.

No individual exceeded 2 rem (20 mSv) TED in 2016.

Department of Energy Idaho Operations Office (DOE IOO)

The DOE Idaho Operations Office monitored 228 individuals in 2016, and of those, 7 individuals had measurable TED. The collective TED for 2016 was 0.124 person-rem (1.240 person-mSv), which was a 17 percent increase from 2015 (0.106 person-rem [1.060 person-mSv]). The largest individual TED for the year was 0.033 rem (0.330 mSv).

No individual exceeded 2 rem (20 mSv) TED in 2016.

Hanford	Percent Change for Last Year 2015 2016	Percent Change for Past 3 Years 2014 2016	Percent Change for Past 5 Years 2012 2016
	-20.8% ▼	28.7% ▲	-7.7% ▼

* Up arrows indicate an increase in change. Down arrows indicate a decrease in change.

Description of Activities at the Hanford Site

The 2016 collective TED at Hanford was 90.099 person-rem (900.990 person-mSv), a 21 percent decrease compared with 2015 (113.801 person-rem [1,138.010 person-mSv]).

At Hanford, the collective dose decrease is associated with a change in work activities at the plutonium finishing plant facility. These included the dismantlement of two large glove boxes in the process lines as well as the cleanout of the plutonium reclamation facility canyon which was completed in late 2015/early 2016. There also was decreased work activity with materials requiring extremity monitoring. Due to changes in funding, several Hanford projects continued to operate at minimal levels.

Description of Activities at the Hanford Site (continued)

Hanford Site

There were 4,284 individuals monitored at Hanford in 2016. Of these, 1,218 individuals had measurable TED, which was a 77 percent increase from 2015 (see Exhibit 3-12 for more details). The TED decreased 34 percent from 62.612 person-rem (626.120 person-mSv) in 2015 to 41.109 person-rem (411.090 person-mSv) in 2016.

No individual exceeded 2 rem (20 mSv) TED in 2016.

The Office of River Protection (ORP)

In 2016, the ORP monitored 2,655 individuals, which included 944 individuals with a measurable TED, a 46 percent increase from 2015 (see Exhibit 3-12 for more details). The 2016 collective TED decreased 3 percent from 38.608 person-rem (386.080 person-mSv) in 2015 to 37.391 person-rem (373.910 person-mSv) in 2016.

No individual exceeded 2 rem (20 mSv) TED in 2016.

Pacific Northwest National Laboratory (PNNL)

In 2016, PNNL monitored 2,470 individuals, and of these, 420 individuals had measurable TED, a 9 percent decrease from 2015 (see Exhibit 3-12 for more details). The collective TED at PNNL in 2016 was 11.599 person-rem (115.990 person-mSv), an 8 percent decrease from the previous year (12.581 person-rem [125.810 person-mSv]).

The collective dose for 2016 compared with 2015 was lower due to a reduction of elevated risk radiological work at PNNL.

No individual exceeded 2 rem (20 mSv) TED in 2016.

In addition to information provided in *Exhibit 3-13*, 22 DOE sites reported descriptions of activities related to occupational exposure, as requested in the REMS Reporting Guide, Item 1. The full text of these descriptions can be found in section 3.4.4. In this section, increases and decreases in the collective dose at DOE sites range from improvements in implementing the ALARA process to changes in decommissioning activities. Overall, the sites reported minimal changes in collective dose.

3.4.4 Additional Site Descriptions

The following descriptions were provided by the sites not previously included in *Exhibit 3-13*. The REMS Reporting Guide, Item 1, specifies that the sites should provide a description of activities conducted relating to the collective radiation exposure received.

Ames

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.

There were 190 individuals monitored in 2016, and of these, 41 individuals had a measurable TED, a 5 percent increase from 2015. The collective TED was 1.240 person-rem (12.400 person-mSv) in 2016, which was a 1 percent decrease from 2015.

No individuals exceeded 2 rem (20 mSv) TED for this monitoring year.

The use of X-ray devices and remediation of radiological legacy contamination are the primary paths of potential exposure. The laboratory has 23 X-ray systems and one Mossbauer spectroscopy system. Limited radioactive material research activities are conducted utilizing microgram quantities.

ANL

Argonne National Laboratory (ANL) is one of the 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.

There were 1,786 individuals monitored in 2016, and of these, 70 individuals had a measurable TED, a 16 percent decrease from 2015. The collective TED was 13.080 person-rem (130.800 person-mSv) in 2016, which was a 12 percent decrease from 2015.

No individuals exceeded 2 rem (20 mSv) TED for this monitoring year.

The decrease in collective TED is attributed to the reduction of work activities in Building 211. No radioisotope production irradiations were performed in the Low Energy Accelerator Facility in 2016 as compared to the previous year of eight to ten production irradiations. The Alpha Gamma Hot Cell Facility removed the last piece of reactor fuel and cladding from the hot cells in 2015, reducing the dose rates for personnel working on downsizing and removing large equipment left in the hot cells.

BNL

Brookhaven National Laboratory (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.

There were 3,178 individuals monitored in 2016, and of these, 84 individuals had a measurable TED, a 37 percent decrease from 2015. The collective TED was 3.217 person-rem (32.170 person-mSv) in 2016, which was a 4 percent decrease from 2015.

The slight decrease in total dose was primarily due to effective radiation protection practices and procedures. The highest individual dose was 0.261 rem.

No individuals exceeded 2 rem (20 mSv) TED for this monitoring year.

ETEC

The Energy Technology Engineering Center (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. With the closing of DOE operations, the focus turned to the disposition of government property, cleanup of facilities, the investigation and remediation of soil and groundwater, demolition of facilities, and site restoration. Area IV is undergoing characterization for cleanup of the area. ETEC is currently in a safe shutdown mode, pending the completion of the Environmental Impact Statement.

There were 5 individuals monitored in 2016, and of these, 2 individuals had a measurable TED, a 33 percent decrease from 2015. The collective TED was 0.089 person-rem (0.890 person-mSv) in 2016, which was a 31 percent increase from 2015.

No individuals exceeded 2 rem (20 mSv) TED for this monitoring year.

The former ETEC facility is not operational and only maintenance activities are being performed until the Environmental Impact Statement is completed.

Fermilab

Fermi National Accelerator Laboratory (Fermilab) provides leadership and resources for qualified researchers to conduct basic research at the frontiers of high-energy physics and related disciplines.

In 2016, Fermilab reported 1,382 monitored individuals, and of these, 232 individuals had a measurable TED, a 1 percent decrease compared with 2015. During 2016, the collective TED was 11.930 person-rem (119.300 person-mSv), which was a 28 percent decrease from 2015.

During 2016, the primary activities at Fermilab that resulted in occupational radiation exposures were the upgrade and repair activities of the Fermilab accelerator complex. On August 1, 2016, Fermilab began a maintenance and upgrade shutdown to prepare the accelerator and associated facilities for new experiments at much larger beam intensities to support the current and future research at the laboratory. The vast majority of the work performed during this shutdown was also intended to improve operational reliability and hence, reduced maintenance needs in the future. This included upgrades in the Booster, Switchyard, Recycler, Booster Neutrino Beamline, and NuMI areas.

KC-NSC

The National Nuclear Security Administration (NNSA) Kansas City National Security Campus (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.

In 2016, KC-NSC reported 97 monitored individuals, and of these, 24 individuals had a measurable TED compared with 12 persons with a measurable TED in 2015. This increase in individuals with a measurable TED was concentrated primarily in one department that significantly increased production on an on-going Life Extension Program (LEP) weapons program. The collective TED was very low, 0.063 person-rem (0.630 person-mSv) in 2016 and 0.020 person-rem (0.200 person-mSv) in 2015.

No individuals exceeded 2 rem (20 mSv) TED for this monitoring year.

LBNL

Lawrence Berkeley National Lab (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.

The total number of employees monitored for radiation exposure at LBNL in 2016 was 924, and of these, 13 individuals had a measurable TED, a slight increase from 11 in 2015. The collective TED was 0.823 person-rem (8.230 person-mSv), an increase of 3 percent from 2015.

The slight increase in the collective TED reflects the steady experimental workload performed in the Center for Functional Imaging (CFI). The radiological activities at CFI contributed to 80% of the collective TED. The research at the CFI includes, but not limited to, new radiopharmaceutical (F-18/C-11) development.

No individual exceeded 2 rem (20 mSv) TED for this monitoring year.

LLNL

Lawrence Livermore National Laboratory (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. Support of these operations requires the use of a wide range of radiation-producing devices (e.g., X-ray machines, accelerators, electron-beam welders) and radioactive materials. 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.

In 2016, the combined total number of employees monitored for radiation exposure at LLNL, including LLNL and LLNL-Nevada, was 8,738, of these—98 individuals had a measurable TED, a 7 percent decrease from 2015. The collective TED was 8.215 person-rem (82.150 person-mSv), an 8 percent increase from 2015.

In 2016, 8,507 people were monitored at LLNL, and of these, 86 people had a measurable TED, a 13 percent decrease from 2015. The collective TED for LLNL in 2016 was 7.701 person-rem (77.010 person-mSv), a 7 percent increase from 2015. The increase in measurable TED reflects the addition of travel records that have not previously reported.

No individual exceeded 2 rem (20 mSv) TED for this monitoring year.

LLNL-Nevada is a DOE facility that serves as a national resource of scientific, technical, and engineering capability with a special focus on national security.

For 2016, LLNL-Nevada monitored 231 individuals and 12 individuals had a measurable TED, a 71 percent increase from 2015. The collective TED for LLNL-Nevada was 0.514 person-rem (5.140 person-mSv) compared with 0.383 person-rem (3.830 person-mSv) in 2015.

No individual exceeded 2 rem (20 mSv) TED for this monitoring year.

NBL

On May 15, 2016, the Office of Science reorganized the New Brunswick Laboratory, resulting in a new NBL Program Office that is independent of the facility and focused entirely on mission performance and managing the CRM production program. The NBL program, as another new Federally-staffed organization, reports to the DOE Office of Science Argonne Site Office, is tasked to address the legacy materials remaining in the current laboratory building, distributes certified reference materials (CRMs) at the Program Office's request, and assists in relocating the NBL material inventory to other locations within the DOE complex. The prior DOE New Brunswick Laboratory operations in Building 350 have ceased and the name "New Brunswick Laboratory" is no longer used. Building 350 current and anticipated operations are now under the auspices of the Argonne Radiation Protection Program (RPP) as of June 17, 2016.

However, prior to June 2016, NBL monitored 26 individuals, and of these, 4 individuals had a measurable TED. The collective TED at NBL for 2016 was 0.096 person rem (9.600 person mSv). No radioisotope production irradiations were performed, and dose rates were reduced due to the removal of fuel cladding material from the hot cells in 2015.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

NNSS

The Nevada National Security Site (NNSS) is located approximately 65 miles northwest of Las Vegas, Nevada. 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. Current activities include: operating low-level radioactive and mixed-waste disposal facilities; assembling and executing subcritical experiments; conducting confined critical experiments; assembling/disassembling special experiments; operating the pulsed X-ray machines and neutron generators; conducting accelerator experiments; developing, testing, and evaluating radiation detectors; developing and providing emergency response training; conducting surface cleanup and site characterization of contaminated land areas; managing environmental activity of the University of Nevada system; and managing non-nuclear test operations, such as controlled spills of hazardous materials.

In 2016, NNSS monitored 1,619 people, and of these, 84 people had a measurable TED, a 14 percent decrease compared with 2015. The collective TED for 2016 at NNSS was 3.295 person-rem (32.950 person-mSv), which represents a 35 percent decrease in TED from 2015.

The decrease in dose was caused by delayed activities associated with critical experiments and the termination of accelerator activities.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

NREL

The National Renewable Energy Laboratory (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.

In 2016, NREL monitored 11 people, and of these, 7 people had a measurable TED, a 175 percent increase from 2015. The collective TED increased by 21 percent from 2015 (0.028 person-rem [0.280 person-mSv]) to 2016 (0.034 person-rem [3.400 person-mSv]).

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

OST

The Office of Secure Transportation (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.

The TSS is a national security transportation asset specifically assigned to transport cargoes in the national interest for which commercial carriage is prohibited. OST is also tasked to be the Federal air carrier to support U.S. weapon accident, national nuclear, and radiological response capabilities. In support of the active U.S. nuclear weapon stockpile, OST delivers limited life components to the Department of Defense and NNSA production sites. OST also provides secure ground transportation services to other DOE and NNSA program offices, to the Department of the Navy, and to the U.S. Nuclear Regulatory Commission (NRC), and to other Federal agencies. Federal Agents provide physical security and safety inspection of air and ground transporters and cargoes and thus are primarily the OST employees enrolled in the OST dosimetry monitoring program.

OST employees are monitored and OST uses ALARA-based instructions to ensure that 10 CFR 835 occupational worker limits are observed. OST ES&H staff track, and on occasion, will direct cargo loading revisions to minimize radiation exposure to both DOE contractor loading personnel as well as OST Federal Agents. With DOE site concurrence, OST prefers to track OST employee dose under OST's dosimetry reporting program rather than having employees be tracked by each DOE site that the TSS services.

In 2016, OST monitored 344 individuals, and of these, 3 individuals had a measurable TED, a 50 percent increase from 2015. The TED to OST workers in 2016 was 0.072 person-rem (0.720 person-mSv), which represents a 148 percent increase from the total person-rem dose in 2015.

No individual exceeded their assigned ACL in 2015.

Pantex

The DOE/NNSA Pantex Plant is the nation's only facility for assembly and disassembly of nuclear explosives. The operations that contribute the majority of the dose to Pantex Plant workers are operations that expose them to large numbers of bare weapon pits (the pits contain significant quantities of SNM). These operations include nuclear explosive assembly/disassembly operations, weapon dismantlement programs, life-extension programs, SNM Component Re-qualification, and SNM staging.

In 2016, Pantex monitored 4,588 individuals, and of these, 295 individuals had a measurable TED, a 2 percent decrease from 2015. The TED to Pantex Plant workers in 2016 was 25.918 person-rem (259.180 person-mSv), which represents a 15 percent increase from the total person-rem dose in 2015.

No individual exceeded their assigned ACL in 2015.

The primary reason for the increase in population dose in 2016 was the union strike in 2015 which curtailed production near the end of the year with make-up work performed in 2016.

PGDP

The Paducah Gaseous Diffusion Plant (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.

In 2016, the PGDP monitored 2,183 individuals, which included 559 individuals with a measurable TED, a 66 percent increase compared with 2015. The overall collective TED for the PGDP was 6.201 person-rem (62.010 person-mSv), a 12 percent decrease from 2015. The following description provides a breakdown of the various activities at this site.

The depleted uranium hexafluoride (DUF_6) contractor monitored 356 individuals, and of these, 170 received a measurable TED. The collective TED for 2016 was 3.162 person-rem (31.620 person-mSv). The primary reason for this 43 percent decrease was a change in the plant's operational status. There were a number of issues at a sister plant that lead to the shutdown of the Paducah facility. Additionally, all support functions had limited support which also reduced the overall collective dose.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

The DOE oversight contractor's collective TED for the 2016 monitoring year was 0.403 person-rem (4.030 person-mSv). In 2016, the number of individuals with a measurable TED increased to 56 compared with 39 in 2015. The primary reason for this change was an increase in work activities in and around the depleted uranium facility (DUF), such as DOE oversight, fence work, mowing, and parking lot maintenance.

The DOE Paducah Deactivation Project contractor's collective TED for the 2016 monitoring year was 2.636 person-rem (26.360 person-mSv) and included 333 individuals with a measurable TED. The primary reason for this change was a full year of deactivation work activities in the former C-400 Cleaning facility. There were no unusual events related to occupational radiation exposure at facilities for 2016.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

PORTS

The Portsmouth Gaseous Diffusion Plant (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 is shut down and is currently undergoing decontamination and decommissioning (D&D).

In 2016, PORTS monitored 2,541 individuals, which included 40 people with a measurable TED, a 32 percent decrease from 2015. The collective TED in 2016 at PORTS was 2.509 person-rem (25.090 person-mSv), a 47 percent decrease compared with 2015. The following provides a breakdown of the various activities at this site.

In 2016, there was a change in contractors which provide D&D services for PORTS. The DOE D&D contractor's exposure information for 2016 covers activities performed under the DOE contract and includes environmental remediation, facility decontamination, and uranium barter transfers at the Portsmouth Site. The collective TED until April 2016 was zero and included 160 monitored individuals. For the remaining year, the collective TED for 2016 was 0.928 person-rem (9.280 person-mSv), a 62 percent decrease compared with 2015. The number of individuals with a measurable TED decreased by 33 percent in 2016 (22) compared with 2015 (33). The majority (95 percent) of this dose on site comes from the Barter Project. As a result of continual reduction in production, the associated doses have also decreased. The major reasons for this reduction were better work practices, better cylinder management in the yards that have segregated and stored heel cylinders, and better worker awareness of the exposure associated with the heel cylinders.

The DUF_6 contractor's collective TED for 2016 was 1.581 person-rem (15.810 person-mSv), a 30 percent decrease compared with 2015. The number of individuals with a measurable TED decreased by 31 percent in 2016 (18) compared with 2015 (26). The primary reason for this change was a work stoppage/reduction caused by an unplanned event.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

PPPL

The DOE's Princeton Plasma Physics Laboratory (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.

In 2016, data were submitted for 408 individuals, and of these, 78 individuals had a measurable TED, a 38 percent decrease compared with 2015 (126 individuals with measurable TED). The collective TED decreased by 50 percent from 2015 (0.623 person-rem [6.230 person-mSv]) to 2016 (0.311 person-rem [3.110 person-mSv]).

The primary reason for this change was the shortened run-period of PPPL's primary experiment, the NSTX-U test cell, after it went into extended maintenance. There also was a conversion from monthly to quarterly dosimetry for a portion of 2016.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

SLAC

The National Accelerator Laboratory (SLAC) is one of 10 DOE Office of Science laboratories and is operated by Stanford University on behalf of DOE. Since its opening in 1962, SLAC has been helping create the future. SLAC built the world's longest particle accelerator and discovered some of the fundamental building blocks of matter.

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. The main instrument of research is the 3.2-km linear accelerator (LINAC), which can generate high-intensity beams of electrons and positrons up to 50 gigaelectronvolts (GeV). New research areas and projects at SLAC have often evolved as the offspring of the original linear accelerator and storage rings.

Sections of the linear accelerator that defined the lab and its mission in its formative years are still driving electron beams today as the high-energy backbone of two cutting-edge facilities. The world's first hard X-ray free-electron laser, the LINAC coherent light source (LCLS), began operating in 2009. The LCLS uses the last kilometer of the SLAC LINAC. The facility for accelerator science and experimental test in LINAC was completed in 2011 to study plasma acceleration, using short, intense pulses of electrons and positrons to create an acceleration source called a plasma wakefield accelerator.

There is also an active program in the development of accelerators, radio frequency (RF) power sources, detectors, and new sources and instrumentation for synchrotron radiation research. Another facility, Stanford synchrotron radiation lightsource, has a smaller storage ring, the Stanford positron-electron asymmetric ring (SPEAR3), and a separate, shorter linear accelerator and a booster ring for injecting accelerated beams of electrons into SPEAR3. The klystron test laboratory manufactures all the klystrons used in SLAC accelerators, as well as novel structures and components for future accelerators; it supports RF operations of SLAC accelerators; and it operates a 70-MeV X band research accelerator and laser facility capable of producing sub-picosecond beam bunches.

The 2016 report contained 2,036 records, which included 6 people with a measurable TED, a 200 percent increase compared with 2015. Collective TED in 2016 was 0.170 person-rem (1.700 person-mSv), a 146 percent increase compared with 2015. The 2016 collective TED is still low and reflects normal routine operations at SLAC.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

SNL

The Sandia National Laboratories (SNL) radiological operations include operating a research reactor, gamma irradiation facility, hot cell facility, and several accelerators. Additionally, SNL conducts light laboratory work involving X-ray machines, tracer radionuclides, and waste operations.

In 2016, SNL monitored 1,853 individuals, and of these, 68 individuals had a measurable TED, a 31 percent decrease from 2015. The total collective TED reported was 2.756 person-rem (27.560 person-mSv), a 48 percent decrease from 2015.

The 2016 TED decrease is attributed to the no waste and material disposition campaigns occurring at the Auxiliary Hot Cell Facility (AHCF) and the Annular Core Research Reactor (ACRR) not operating for a large part of the year.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

SPRU

The Separations Process Research Unit (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.

In 2016, SPRU monitored 202 individuals, and of these, 101 had a measurable TED, a 32 percent decrease compared with 2015. The collective TED for 2016 was 47.541 person-rem (475.410 person-mSv), a 31 percent decrease from 2015.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

The primary reason for this reduction was the removal of the more significant source term activity. The focus of project activities in 2016 included commencement of G2 open air demolition and H2 Building process equipment removal, concrete scabbling and sump debris removal. The activities that resulted in the major person-rem contribution were the completion of preparations for G2 open air demolition and H2 Building concrete scabbling, removal of process piping, equipment, and debris from the H2 Tunnel. Surveillance and maintenance activities, process and shipment of low activity water, and the shipment of low activity debris also contributed to the collective TED.

TJNAF

The Thomas Jefferson National Accelerator Facility (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.

In 2016, TJNAF monitored 1,201 individuals, which included 30 individuals with a measurable TED, a 36 percent decrease from 2015. The 2016 collective TED for TJNAF was 0.777 person-rem (7.770 person-mSv), a decrease of 77 percent from 2015.

No individual exceeded 2 rem (20 mSv) TED for this monitoring year.

The major contributor to the collective TED was the extensive upgrade of the Hall C high power beam dump area. In general, collective TED was attributed to maintenance, modification, and repair to activated components associated with the continuous electron beam accelerator facility and other ancillary activities (e.g., transport, storage, and disposal of radioactive materials). Typically, collective TED fluctuates up or down from year to year, depending on maintenance associated with unique experimental setups performed in radiation areas. The decrease in collective TED was commensurate with the type of work performed by the individuals in 2016.

UMTRA

The Uranium Mill Tailings Remedial Action Project (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 day. The trains have up to 36 railcars, each holding four lidded containers, for a total of about 5,000 tons of tailings per shipment. Tailing shipments began in April 2009 and are expected to continue through 2025.

In 2016, UMTRA monitored 153 individuals, which included 131 individuals with a measurable TED, a 52 percent increase from 2015. The collective TED for 2016 was 7.044 person-rem (70.440 person-mSv) and represented a 2 percent decrease from 2015.

The primary radiological concerns are possible airborne exposure from wind and dust and the release of radon as the tailings waste are unearthed and loaded on the railcars.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

WIPP

The Waste Isolation Pilot Plant (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.

In 2016, WIPP monitored 598 individuals, and of these, 22 individuals had measurable TED, an 83 percent increase compared with 2015. The collective TED for 2016 was 0.311 person-rem (3.110 person-mSv), which represented an increase of 93 percent from 2015 (0.161person-rem [1.610 person-mSv)]).

The primary reason for this change was due to decontamination efforts in the WIPP underground as well as resumption of a limited amount of activities.

No individual exceeded 2 rem (20 mSv) TED for this monitoring year.

WVDP

The West Valley Demonstration Project (WVDP) is a unique operation within DOE. It came into being through the WVDP Act of 1980. The Act requires the Department 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 the Department. 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.

In 2016, WVDP monitored 391 individuals, and of these, 147 individuals had measurable TED, a 20 percent increase from 2015. The collective TED for 2016 was 41.122 person-rem (411.220 person-mSv), which represented a 46 percent increase from 2015.

The major project contributing to dose in 2016 was facility disposition demolition preparation work in the liquid waste cell, all three extraction cells, the off gas cell/off gas blower room, sample storage cell, and the vitrification facility. The high-level waste department prepared the equipment decontamination room, vitrification tunnel, and the chemical process cell crane room for high-level waste canister movements and the removal of the first three casks containing the vitrified high-level waste. The waste operations department activities supported waste packaging and movements onsite and the preparation of the remote handling waste facility operations.

No individual exceeded 2 rem (20 mSv) TED this monitoring year.

3.4.5 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 3-14 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 (54 and 29 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 http://energy.gov/ehss/occupational-radiation-exposure in the Appendices section of the Annual Report.

Exhibit 3-14:
Program Office Dose Data, 2016.

Program Office	Collective TED (person-rem)	Percent Change from 2015	Number with Meas. Dose (TED)	Percent Change from 2015	Avg. Meas. TED (rem)	Percent Change from 2015
Office of Energy Efficiency and Renewable Energy (EE)					**Total Monitored**	**11***
National Renewable Energy Laboratory	0.034	◊	7	◊	0.005	◊
EE Totals	**0.034**	◊	**7**	◊	**0.005**	◊
Office of Environmental Management (EM)					**Total Monitored**	**22,866***
East Tennessee Technology Park	0.114	◊	3	◊	0.038	◊
Energy Technology Engineering Center	0.089	◊	2	◊	0.045	◊
Hanford Site	41.109	-34% ▼	1,218	**77%** ▲	0.034	-63% ▼
Idaho Site (ICP, AMWTP and DOE IOO)	56.129	-25% ▼	633	4% ▲	0.089	-28% ▼
Nevada National Security Site	0.000	◊	0	◊	0.000	◊
Oak Ridge National Laboratory	29.542	11% ▲	206	-7% ▼	0.143	19% ▲
Office of River Protection	37.391	-3% ▼	944	46% ▲	0.040	-34% ▼
Paducah Gaseous Diffusion Plant	6.201	-12% ▼	559	66% ▲	0.011	-47% ▼
Portsmouth Gaseous Diffusion Plant	2.509	-47% ▼	40	-32% ▼	0.063	-22% ▼
Savannah River Site	**111.338**	17% ▲	**2,799**	49% ▲	0.040	-21% ▼
Separations Process Research Unit	47.541	-31% ▼	101	-32% ▼	**0.471**	1% ▲
Service Center Personnel	0.232	◊	14	◊	0.017	◊
Uranium Mill Tailings Remedial Action Project	7.044	-2% ▼	131	52% ▲	0.054	-36% ▼
Waste Isolation Pilot Plant	0.311	◊	22	◊	0.014	◊
West Valley Demonstration Project	41.122	**46%** ▲	147	20% ▲	0.280	**21%** ▲
EM Totals	**380.672**	**-8%** ▼	**6,819**	**41%** ▲	**0.056**	**-35%** ▲
National Nuclear Security Administration (NNSA)					**Total Monitored**	**33,209***
Kansas City National Security Campus	0.063	◊	24	◊	0.003	◊
Lawrence Livermore National Laboratory	8.215	8% ▲	98	-7% ▼	0.084	16% ▲
Los Alamos National Laboratory	**95.565**	-2% ▼	1,106	-3% ▼	0.086	1% ▲
Office of Secure Transportation	0.072	◊	3	◊	0.024	◊
Nevada National Security Site	3.295	-34% ▼	84	-13% ▼	0.039	-25% ▼
Pantex Plant	25.918	15% ▲	295	-2% ▼	**0.088**	**17%** ▲
Sandia National Laboratories	2.756	-48% ▼	68	-31% ▼	0.041	-24% ▼
Y-12 National Security Complex	72.807	**26%** ▲	**1,460**	**22%** ▲	0.050	3% ▲
NNSA Totals	**208.691**	**7%** ▲	**3,138**	**6%** ▲	**0.067**	**0%**
Office of Nuclear Energy, Science and Technology (NE)					**Total Monitored**	**4,307***
Idaho National Laboratory	36.541	-24% ▼	640	-11% ▼	0.057	-14% ▼
NE Totals	**36.541**	**-24%** ▼	**640**	**-11%** ▼	**0.057**	**-14%** ▼
Office of Science (SC)					**Total Monitored**	**17,307***
Ames Laboratory	1.240	-1% ▼	41	5% ▲	0.030	-5% ▼
Argonne National Laboratory	13.080	-12% ▼	70	-16% ▼	**0.187**	5% ▲
Brookhaven National Laboratory	3.217	-4% ▼	84	-37% ▼	0.038	**53%** ▲
Fermi National Accelerator Laboratory	11.930	-28% ▼	232	-1% ▼	0.051	-27% ▼
Lawrence Berkeley National Laboratory	0.823	◊	13	◊	0.063	◊
New Brunswick Laboratory	0.096	◊	0	◊	◊	◊
Oak Ridge Institute for Science and Education	0.171	◊	9	◊	0.019	◊
Oak Ridge National Laboratory	**40.009**	**20%** ▲	412	**9%** ▲	0.097	10% ▲
Pacific Northwest National Laboratory	11.599	-8% ▼	**420**	-9% ▼	0.028	1% ▲
Princeton Plasma Physics Laboratory	0.311	◊	78	◊	0.004	◊
Service Center Personnel	0.036	◊	2	◊	◊	◊
SLAC National Accelerator Laboratory	0.170	◊	6	◊	0.028	◊
Thomas Jefferson National Accelerator Facility	0.777	◊	30	◊	0.026	◊
SC Totals	**83.459**	**-4%** ▼	**1,401**	**-8%** ▼	**0.060**	**4%** ▲

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

Transient individuals, or transients, are defined as individuals who are monitored at more than one DOE site during the calendar year. For the purpose of this report, a DOE site is defined as a geographic location. 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 3-15* shows the dose distribution and total number of transient individuals from 2012 to 2016. 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, 3.4 percent of the collective TED. The collective TED for transients increased slightly from 21.6 person rem (216 person-mSv) in 2015 to 23.5 person-rem (235 person-mSv) in 2016. The average measurable TED decreased 8 percent from 0.053 rem (0.530 mSv) in 2015 to 0.049 rem (0.490 mSv) in 2016. The decrease of the average measurable TED was a result of the 18 percent increase in the number of transient individuals with measurable dose (410 in 2015 to 484 in 2016) and the 9 percent increase of 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

3.6.1 Prior Years

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 3-16* and *Exhibit 3-17* 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 3-16* and *Exhibit 3-17* show the collective dose, average measurable dose, and number of workers with a measurable dose from 1974 to 2016. 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 D&D activities.

Exhibit 3-15:
Dose Distribution of Transient Individuals, 2012–2016.

	Dose Ranges (TED in rem)	2012	2013	2014	2015	2016
Transients	Less than measurable	1,884	1,501	2,158	2,151	2,014
	Measurable <0.100	418	371	379	360	422
	0.100–0.250	52	26	41	35	46
	0.250–0.500	19	14	12	10	14
	0.500–0.750	2	1		3	1
	0.750–1.000	1		1	2	1
	1.0–2.0					
	>2.0					
	Total number of individuals monitored*	2,376	1,913	2,591	2,561	2,498
	Number with measurable dose	492	412	433	410	484
	% with measurable dose	21%	22%	17%	16%	19%
	Collective TED (person-rem)	28.445	21.053	21.400	21.636	23.491
	Average measurable TED (rem)	0.058	0.051	0.049	0.053	0.049
All DOE	Total number of records for monitored individuals	83,043	71,582	75,447	75,557	77,836
	Number of individuals with measurable dose	10,461	9,903	9,501	10,024	12,005
	% of total monitored individuals who are transient	2.9%	2.7%	3.4%	3.4%	3.2%
	% of the number of individuals with measurable dose who are transient	4.7%	4.2%	4.6%	4.1%	4.0%

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

Exhibit 3-16:
Collective Dose and Average Measurable Dose, 1974–2016.

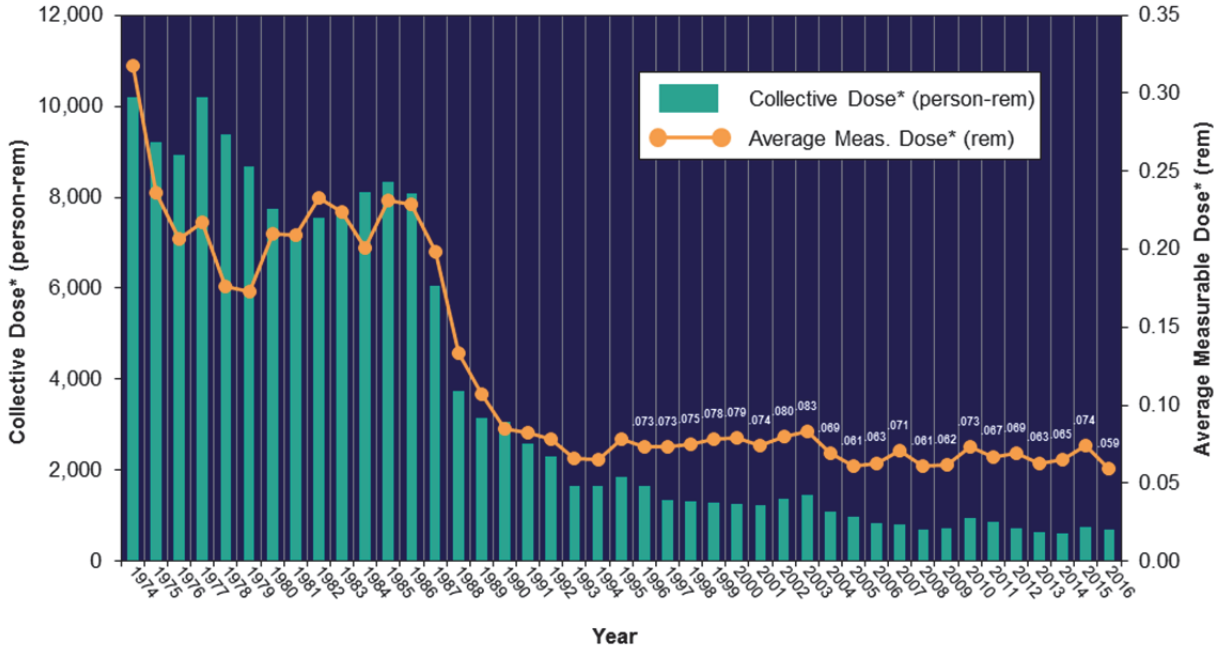
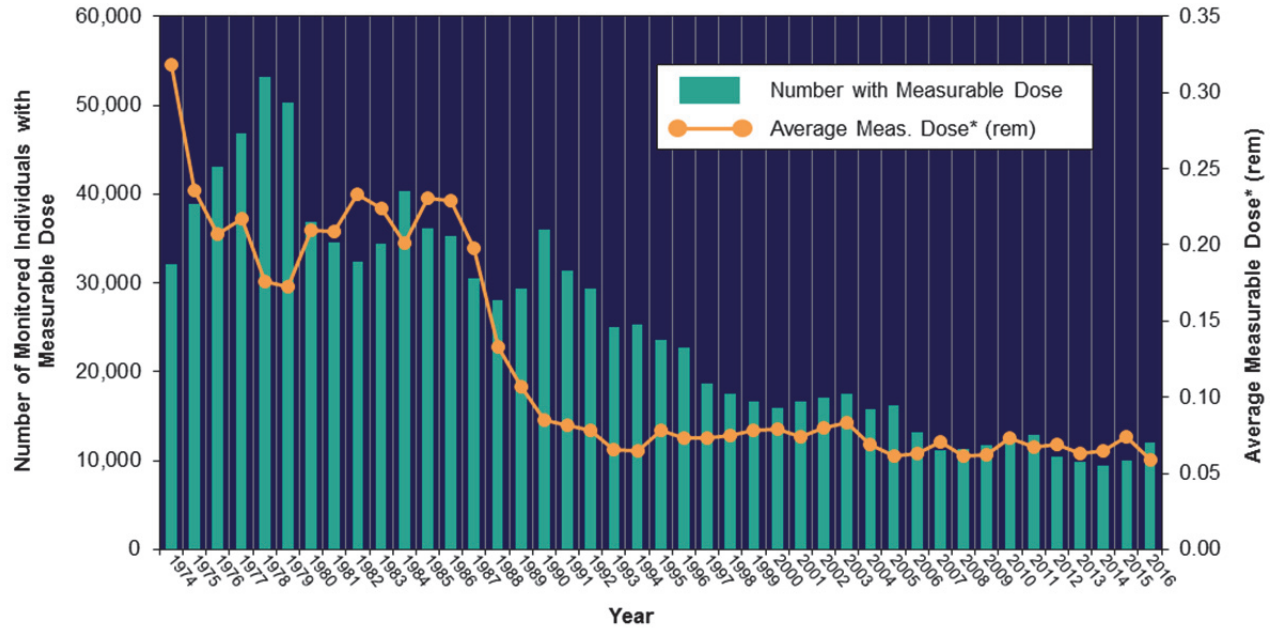


Exhibit 3-17:
Number of Workers with Measurable Dose and Average Measurable Dose, 1974–2016.



* 1974–1989 collective dose = DDE
1990–1992 collective dose = DDE + AEDE
1993–2009 collective dose = DDE + CEDE
2010–2016 collective dose = ED + CED

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

3.6.2 Historical Data Collection

Historical information on occupational exposure radiation is presented in section 3.7 of the 2000 and 2001 annual reports. DOE requested the sites to voluntarily provide historical exposure data, and many sites have subsequently responded. No additional sites reported historical data during the year 2016.

Sites that have not yet reported historical dose records are encouraged to contact Ms. Nirmala Rao at DOE (see section 1.2) to obtain further information on reporting these records. This is a request to voluntarily report historical data (records prior to 1987) that are available in electronic form or in whatever format that is most convenient for the site. The data will be stored as reported in REMS, and wherever possible, data will be extracted and loaded into the REMS database for analysis and retrieval. For detailed analysis, read section 3.7 of the 2000 report.

Sites that have voluntarily reported historical data are as follows:

- Fernald Environmental Management Project;
- Hanford Site;
- Idaho National Laboratory;
- Kansas City National Security Campus (formerly Kansas City Plant);
- Lawrence Berkeley National Laboratory;
- Lawrence Livermore National Laboratory;
- Nevada National Security Site;
- Oak Ridge ETTP (formerly K-25 Site);
- Pantex Plant;
- Portsmouth Gaseous Diffusion Plant;
- Rocky Flats Environmental Technology Site;
- Sandia National Laboratories; and
- Savannah River Site.

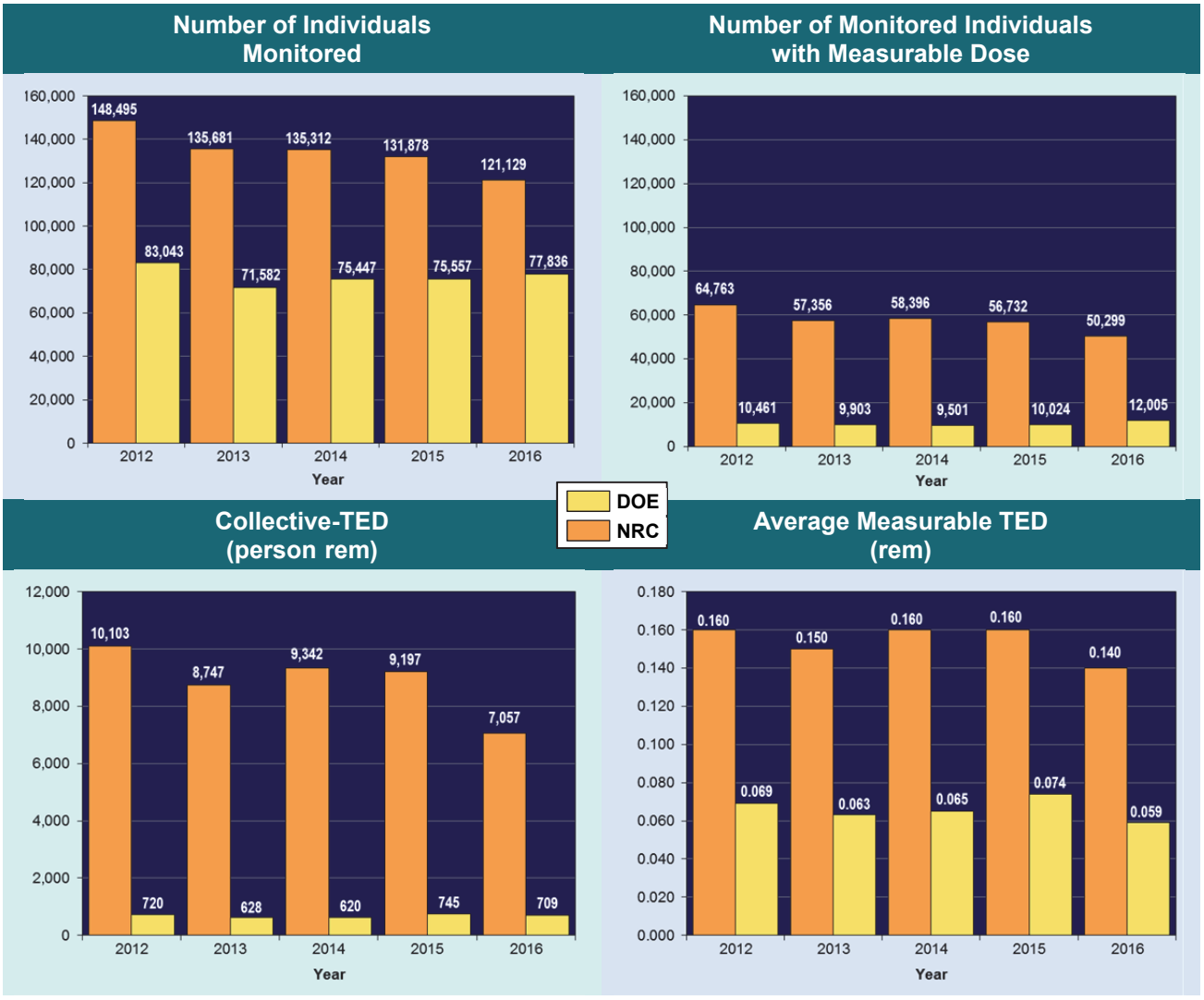
3.7 DOE Occupational Dose in Relation to Other Activities

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 2016 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. Reactor operations account for approximately 76 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 3-18* cover the past 5 years (2012 to 2016). 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 18 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 43 percent of the NRC totals, respectively.

Exhibit 3-18:
Comparison of Occupational Exposure for DOE and NRC, 2012–2016.



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ALARA Activities at DOE

Descriptions of ALARA activities at DOE are provided on the AU web site 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 Environment, Safety, and Health (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:

http://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:

http://energy.gov/ehss/corporate-operating-experience-program

1000 Independence Avenue, SW

Washington, D.C. 20585-1290

E-mail: Ashley.Ruocco@hq.doe.gov

Section Five
Conclusions

5 Conclusions

In 2016, DOE facilities continued to comply with DOE dose limits and ACL and minimize exposures to individuals. Only 15 percent of the monitored workers received a measurable dose, and the average measurable dose received was less than 2 percent of the DOE limit. The collective dose decreased by 5 percent and the number of individuals with measurable dose increased 20 percent. The increase in the number of individuals with measurable dose was the result of increased work activities involving radioactive materials at Oak Ridge and SRS. See *Exhibit 5-1* below for summary data.

The collective TED for all DOE facilities decreased by more than 35 person-rem (350 person-mSv) from 2015 to 2016. Much of the decrease in collective dose has been attributed to D&D activities in reducing the radioactive source term and spent fuel treatments.

The collective dose at DOE facilities has decreased by 92 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:
2016 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 2016.
- The collective TED decreased 5 percent from 745 person-rem (7,450 person-mSv) in 2015 to 709 person-rem (7,090 person-mSv) in 2016.
- The sites contributing the majority of the collective TED were (in descending order): Oak Ridge (OR), Savannah River Site (SRS), Los Alamos National Laboratory (LANL), Idaho, and Hanford. These sites accounted for 75 percent of the collective TED in 2016. The collective TED increased at Oak Ridge and SRS. The increase at Oak Ridge National Laboratory (ORNL) was due largely to increased work activities. The collective TED decreased at LANL, Idaho and Hanford due to improved work processes and reduced operations.
- The collective CED (internal exposure) increased by 19 percent from 51.7 person-rem (517 person-mSv) in 2015 to 61.5 person-rem (615 person-mSv) in 2016, as a result of increases in internal doses across the DOE complex, including 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) increased by 9 percent from 21.6 person-rem (216 person-mSv) in 2015 to 23.5 person-rem (235 person-mSv) in 2016.

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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) (HE,50)
The sum of the committed equivalent doses to various tissues or organs in the body (HT,50), each multiplied by the appropriate tissue weighting factor (wT) (i.e., HE,50 = wTHT,50). CED is expressed in units of rem.

Committed equivalent dose (CEqD) (HT,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 (HT) and the appropriate tissue weighting factor (wT) –that is, Effective dose = ΣwTHT. 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 (DT,R) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor (wR). 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 HT, 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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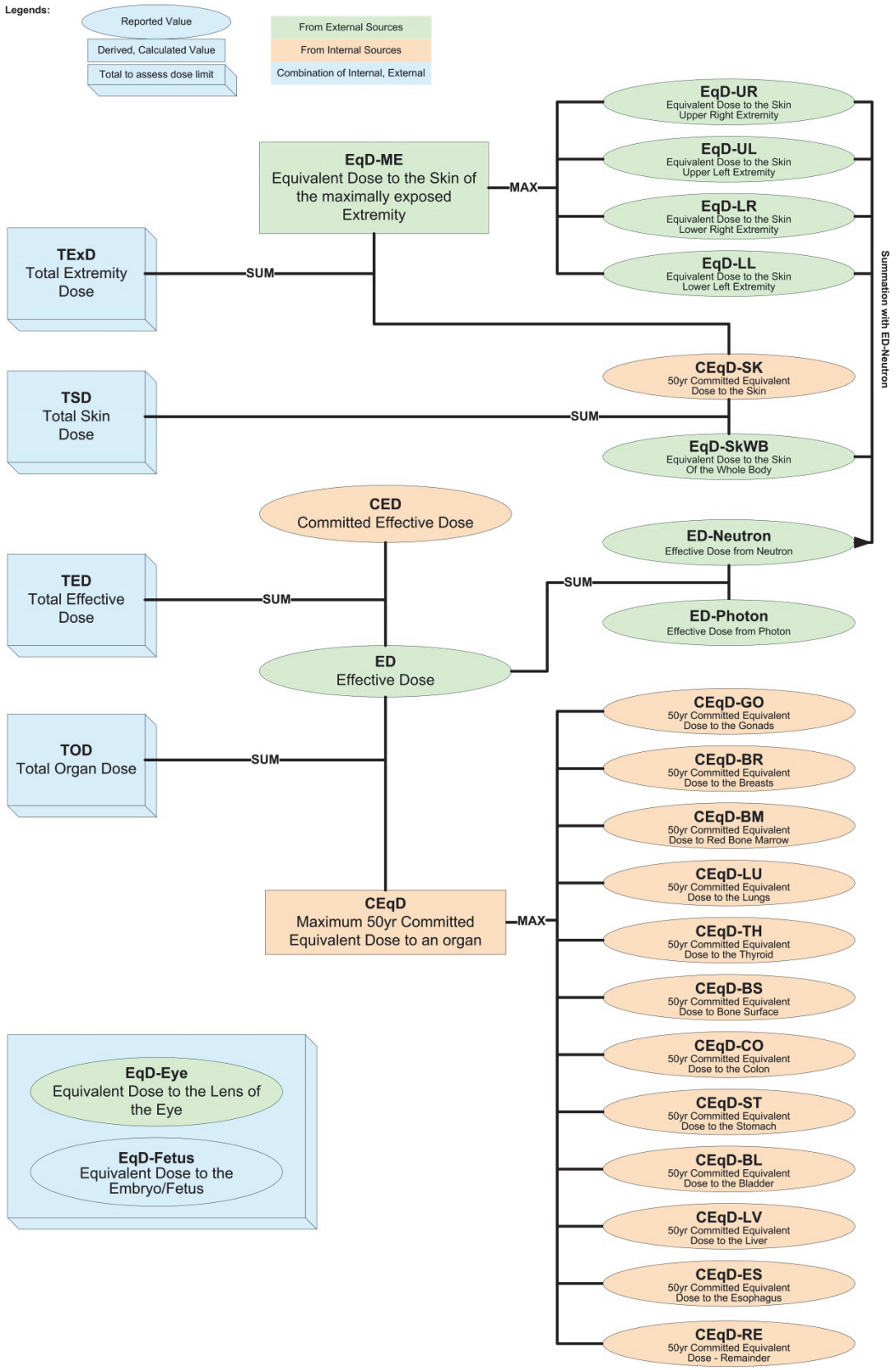
DOE Radiation Exposure Monitoring System (REMS)
Dose Abbreviations, Definitions, and Relationships



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DOE, striving to meet the needs of its stakeholders, is looking for suggestions on ways to improve the *DOE 2016 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.

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Dose Distribution	1	2	3	4	5
Analysis of Individual Dose Data	1	2	3	4	5
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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
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