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Nuclear Material Events Database

Annual Report

Fiscal Year 2015

Prepared for the U.S. Nuclear Regulatory Commission
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ENCLOSURE 1

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ABSTRACT

This report presents information on trending and analysis of incidents/accidents (events) reported to the Nuclear Regulatory Commission (NRC) that involve radioactive material. The events are reported by NRC licensees, Agreement States, and non-licensees, and are recorded in the NRC's Nuclear Material Events Database. The reported events are classified into categories based on event reporting requirements defined in Title 10 of the Code of Federal Regulations. The categories in this report are (1) Lost/Abandoned/Stolen Material, (2) Medical, (3) Radiation Overexposure, (4) Release of Licensed Material or Contamination, (5) Leaking Sealed Source, (6) Equipment, (7) Transportation, (8) Fuel Cycle Process, and (9) Other.

CONTENTS

FIGURES

TABLES

ACRONYMS

ALARA	as low as reasonably achievable
ALI	annual limit on intake
AO	abnormal occurrence
CFR	Code of Federal Regulations
CRHB	California Radiologic Health Branch
DDE	deep dose equivalent
DE	dose equivalent
EDE	effective dose equivalent
EQP	Equipment
EXP	Radiation Overexposure
FCP	Fuel Cycle Process
FY	fiscal year
GTCC	greater than class C
HDR	high dose rate
HLW	high-level waste
IAEA	International Atomic Energy Agency
INL	Idaho National Laboratory
IROFS	item relied on for safety
ISA	integrated safety analysis
LAS	Lost/Abandoned/Stolen Material
LKS	Leaking Sealed Source
LS	least squares
MED	Medical
NA	not applicable
NMED	Nuclear Material Events Database
NR	not recovered
NRC	Nuclear Regulatory Commission
NRCB	NRC Bulletin
OTH	Other
REAC/TS	Radiation Emergency Assistance Center/Training Site
RLM	Release of Licensed Material or Contamination
RSO	radiation safety officer
SDE	shallow dose equivalent

SNM	special nuclear material
SSE	error sum of squares
SSR	regression sum of squares
SST	total sum of squares
TEDE	total effective dose equivalent
TRS	Transportation

EXECUTIVE SUMMARY

The Nuclear Regulatory Commission's (NRC) Nuclear Material Events Database (NMED) contains records of events involving nuclear material reported to the NRC by NRC licensees, Agreement States, and non-licensees. The reported events are classified based on reporting requirements defined by Title 10 of the Code of Federal Regulations. The event reports are evaluated to identify statistically significant trends and events of higher significance (referred to as significant events in this report).

The significant events that occurred in Fiscal Year 2015 are summarized below. Note that a single event may be listed in more than one event type category.

Lost/Abandoned/Stolen Radioactive Sources/Material Events

Fourteen significant events occurred involving the loss of 15 Category 1-3 sources as defined by the International Atomic Energy Agency's *Code of Conduct on the Safety and Security of Radioactive Sources (2004)*. Two Category 1 sources, nine Category 2 sources, and four Category 3 sources were lost; all of which were subsequently recovered except one Category 3 source.

Two events involved the loss (and subsequent recovery) of Category 1 sources (containers of Ir-192 source wafers/disks) during shipment by common carrier.

Eight events involved the loss (and subsequent recovery) of Category 2 sources. Six of the events involved radiography devices; three devices fell from trucks en route to jobsites, two devices were left unattended by the radiographers, and one device was in a truck that was stolen. The seventh event involved the loss of two radiography sources during shipment by common carrier. The eighth event involved the abandonment of an irradiator during an eviction process.

Four events involved the loss (all but one source were subsequently recovered) of Category 3 sources. Two of the events resulted from errors during shipment by common carrier. One event involved a well logging source that fell from a truck en route from a jobsite. The fourth event involved a plutonium-powered pacemaker that was buried with a deceased patient; this source was not recovered.

A fifteenth significant event occurred prior to Fiscal Year 2015 and was recently added to NMED. This event involved the receipt of a Category 3 brachytherapy source at a hospital on a holiday weekend; no authorized user was present. The source was not placed into a controlled area for several days.

Medical Events

Eleven significant events occurred, all of which were classified as potential Abnormal Occurrences. Eight of the events involved doses administered to the wrong site: three during high dose rate brachytherapy, three during Y-90 microsphere treatment, one during prostate brachytherapy, and one during gamma knife treatment. Three events involved overdoses; two during high dose rate brachytherapy and one from an I-131 administration.

In addition to the 11 events above, two other significant events classified as potential Abnormal Occurrences occurred prior to Fiscal Year 2015 and were recently added to NMED. One event involved a high dose rate administration to a wrong site. The other event involved overdoses during brachytherapy treatments.

Radiation Overexposure Events

Three significant events occurred. Two of the events involved radiographers exposed by unshielded radiography sources. In the third event, a technician was briefly exposed to very high radiation levels while transferring a highly radioactive source from one shielded container to another.

Release of Licensed Material or Contamination Events

No significant events occurred.

Leaking Sealed Source Events
No significant events occurred.

Equipment Failure Events
Four significant events occurred. Two of the events involved difficulties retracting radiography sources into their exposure devices. The third event involved the inoperability of an Item Relied On For Safety at a nuclear fuel manufacturing facility. The fourth event involved the misalignment of a gamma knife unit during maintenance which resulted in patient overdoses.

Transportation Events
No significant events occurred.

Fuel Cycle Process Events
One significant event occurred. This event involved the inoperability of an Item Relied On For Safety at a nuclear fuel manufacturing facility.

Other Events
One significant event occurred, which was also classified as a potential Abnormal Occurrence. This event involved a dose to an embryo/fetus that resulted from the administration of I-131 to a pregnant patient.

Nuclear Material Events Database Annual Report: Fiscal Year 2015

1. INTRODUCTION

1.1 Overview and Objectives

Nuclear material event reports are evaluated to identify statistically significant trends and significant events. The reported information aids in understanding why the events occurred and in identifying any actions necessary to improve the effectiveness of the nuclear material regulatory program.

A database for tracking nuclear material events was developed by the Nuclear Regulatory Commission (NRC) in 1981. In 1993, using existing material events databases, the NRC developed a new and more comprehensive database for tracking material events. This database, designated the Nuclear Material Events Database (NMED), contains records of events involving nuclear material reported to the NRC by NRC licensees, Agreement States, and non-licensees. The database is maintained by the Idaho National Laboratory (INL) and contains over 23,000 records of material events submitted to the NRC from January 1990 to present.

The events in this report are classified into the following categories based on event reporting requirements defined by Title 10 of the Code of Federal Regulations (CFR):

- Lost/Abandoned/Stolen Material (LAS),
- Medical (MED),
- Radiation Overexposure (EXP),
- Release of Licensed Material or Contamination (RLM),
- Leaking Sealed Source (LKS),
- Equipment (EQP),
- Transportation (TRS),
- Fuel Cycle Process (FCP), and
- Other (OTH).

A description of categories addressed in this report and associated screening criteria are presented in Appendix A.

1.2 NMED Data

A single occurrence report may be captured in more than one NMED event category. For example, a report may describe a loss of licensed material that also resulted in a radiation overexposure. In such a case, both event categories are recorded in the NMED and identified by the same report number (referred to as an item number in the database).

The data presented in this report are limited to reportable events that occurred between October 1, 2005, and September 30, 2015. The data were downloaded from the NMED on January 13, 2016. Because the NMED is a dynamic database that is updated daily, variations in data may be encountered over time. Furthermore, even though many events were reported and entered in the database for operational experience purposes, only those events required to be reported by 10 CFR are addressed in this report.

This report displays annual trend data for each of the event categories for a 10-year period. A trend analysis was performed on each event category to identify the existence or absence of a statistically

significant trend. If a statistically significant trend exists, the display indicates the direction and approximate rate of change with a trend line. For the purposes of this report, a statistically significant trend exists if the analysis indicates that the computed fit and slope of a least squares linear model is valid at a 95% confidence level. A primer on the statistical methods employed in the trend analysis is presented in Appendix B.

Note that the trending methodology is not normalized; the trend only considers the number of reported events and does not directly account for external issues such as changes to regulatory requirements or changes in the number of licensees. For example, an increasing trend in the number of medical events could be caused by an increase in the number of medical procedures being performed. Likewise, an event type showing a decreasing trend for NRC licensees and an increasing trend for Agreement State licensees could be caused by States becoming Agreement States (resulting in fewer NRC licensees and more Agreement State licensees).

Reporting guidance for Agreement States is provided in the *Handbook on Nuclear Material Event Reporting in the Agreement States*. The handbook is an appendix to the NRC Office of Federal and State Materials and Environmental Management Programs procedure SA-300, *Reporting Material Events*. Access to NMED is available to the staff of NRC, Agreement State, and Federal agencies at http://nmed.inl.gov.

For assistance on searches or other questions, contact Robert Sun (nmednrc@nrc.gov, 301-415-3421).

2. ANALYSIS OF NMED DATA

Event reports submitted to the NRC involving nuclear material are reviewed, categorized, and entered into the NMED. Charts are provided to display trends in annual data for the most recent 10-year period (FY06-15).

2.1 All NMED Events

Figure 1 displays the annual number and trend of NMED events that occurred during the 10-year period. The trend analysis determined that the NRC-regulated events represent a statistically significant decreasing trend (indicated by the trend line). However, the Total events and Agreement State-regulated events do not represent statistically significant trends (indicated by the absence of trend lines). Therefore, variations within the Total and Agreement State values represent random fluctuation around the average of the data.

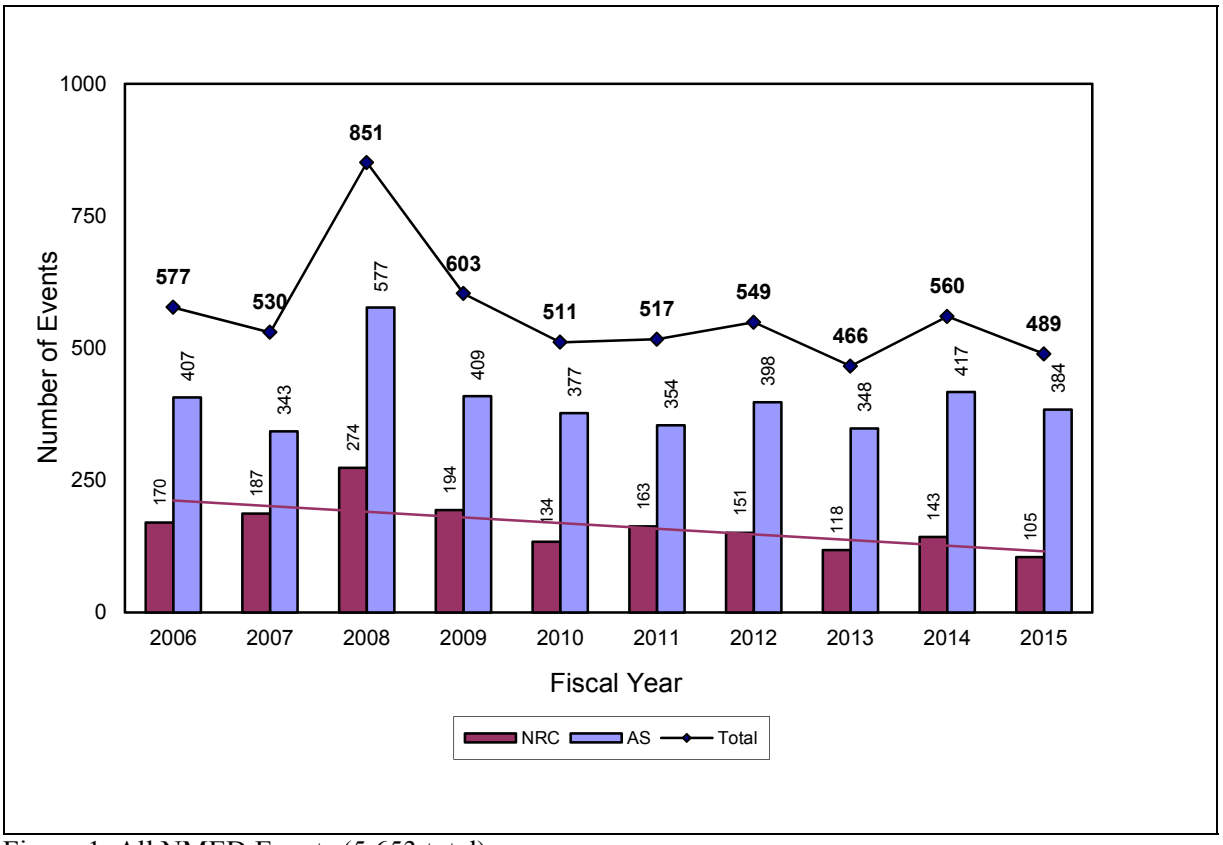

Figure 1. All NMED Events (5,653 total)

The following observations are made regarding the data in Figure 1.

- In FY15, 449 occurrences accounted for 489 events; a single occurrence can be classified in different event categories.
- The FY08 and FY09 data include 274 and 65 events respectively that resulted from Wal-Mart's one-time review of their tritium exit sign inventory.
- The most recent year's data are typically many records less than their final value when subsequent updates and late reports are received (see Appendix D, Figure D-1).

- The transition of states from NRC to Agreement State jurisdiction could result in increasing trends in Agreement State data and decreasing trends in NRC data.

Table 1 displays a summary of the trending analysis for all NMED event types included in this report. A more detailed discussion of the trending analysis results can be found in the section of this report devoted to each event type.

Table 1. Summary of Trending Analysis

Event Type	Total	NRC	Agreement State
All NMED Events	-	↘	-
Lost/Abandoned/Stolen Material (LAS)	-	-	-
Medical (MED)	-	-	↗
Radiation Overexposure (EXP)	-	-	-
Release of Licensed Material or Contamination (RLM)	-	-	-
Leaking Sealed Source (LKS)	-	-	-
Equipment (EQP)	-	↘	-
Transportation (TRS)	-	-	-
Other (OTH)	NA	NA	NA
	Total	**Unique**	**Other**
Fuel Cycle Process (FCP)	-	-	-

Notes:

- ↗ indicates a statistically significant increasing trend.
- ↘ indicates a statistically significant decreasing trend.
- - indicates no statically significant trend.
- NA indicates that the data does not support trending analysis.
- The FCP event type differs from other types in that all FCP events are NRC-regulated. Subcategories include Unique and Other (see Section 2.9).

2.2 Lost/Abandoned/Stolen Material

2.2.1 Ten-Year Data

Figure 2 displays the annual number and trend of LAS events that occurred during the 10-year period. The trend analysis determined that the data do not represent statistically significant trends (indicated by the absence of trend lines). Therefore, variations within the annual values represents random fluctuation around the average of the data.

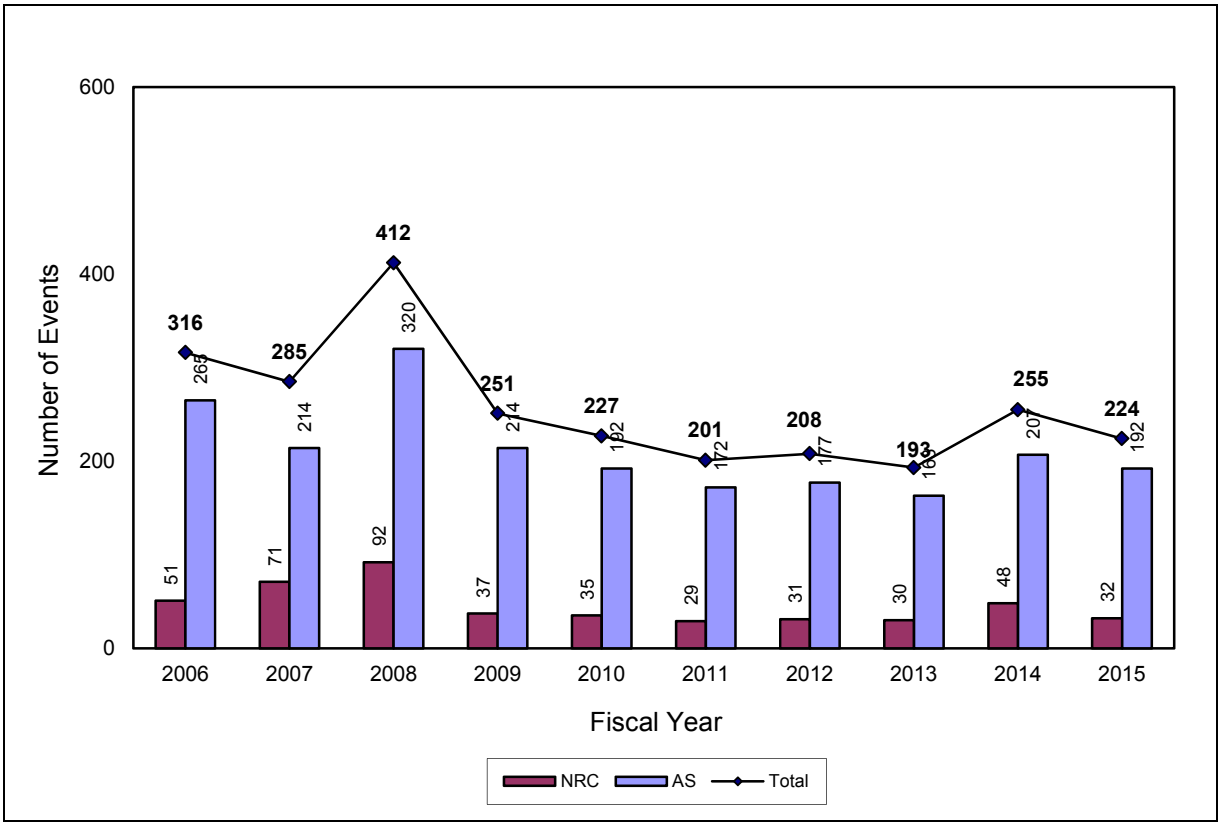

Figure 2. Lost/Abandoned/Stolen Material Events (2,572 total)

The FY08 and 09 data include 143 and 45 LAS events respectively that resulted from Wal-Mart's one-time review of their tritium exit sign inventory.

Appendix C contains a list of radionuclides derived from the International Atomic Energy Agency's (IAEA) *Code of Conduct on the Safety and Security of Radioactive Sources (2004)*. These radionuclides are grouped by the amount of radioactivity into five categories that correspond to the relative hazard, with Category 1 being the most hazardous.

For this report, IAEA Category 1 through 3 source events (excluding irretrievable well-logging source events) are considered significant. Regardless of IAEA category, events involving irretrievable well-logging sources are not considered significant. Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

Table 2 displays the number of sources lost (approximately 4,155, excluding irretrievable well-logging sources) during the 10-year period and the number that have not been recovered (approximately 2,238), grouped by IAEA category where possible. These included two Category 1 sources, 48 Category 2 sources, and 34 Category 3 sources; all of which were recovered, with the exception of one Category 2 and three Category 3 sources.

Table 2. Number of Sources Lost/Abandoned/Stolen (LAS) and Sources Not Recovered (NR) - Excluding Irretrievable Well Logging Sources

Category		Fiscal Year 2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
1	LAS[4]	0	0	0	0	0	0	0	0	0	2	**2**
	NR[5]	0	0	0	0	0	0	0	0	0	0	**0**
2	LAS	4	2	11	2	0	2	3	10	5	9	**48**
	NR	0	0	0	0	0	1	0	0	0	0	**1**
3	LAS	4	1	3	1	4	4	7	3	3	4	**34**
	NR	0	0	0	0	1	0	1	0	0	1	**3**
4	LAS	95	57	71	50	76	44	44	24	53	40	**554**
	NR	48	17	35	25	27	23	14	10	26	21	**246**
5	LAS	110	70	129	76	89	82	83	68	87	71	**865**
	NR	44	19	57	20	29	11	25	8	33	28	**274**
< 5	LAS	0	2	0	2	1	1	0	1	1	1	**9**
	NR	0	0	0	2	1	0	0	0	0	1	**4**
Activity Not Known[1]	LAS	7	3	9	5	13	12	9	7	4	4	**73**
	NR	1	0	0	0	1	0	0	0	0	1	**3**
Nuclide Not Known[2]	LAS	0	2	0	0	0	6	0	1	0	1	**10**
	NR	0	0	0	0	0	5	0	0	0	1	**6**
Other[3]	LAS	303	276	461	274	183	209	193	171	329	161	**2560**
	NR	177	146	383	171	127	139	132	89	257	80	**1701**
Total	**LAS**	**523**	**413**	**684**	**410**	**366**	**360**	**339**	**285**	**482**	**293**	**4155**
	NR	**270**	**182**	**475**	**218**	**186**	**179**	**172**	**107**	**316**	**133**	**2238**

Notes:

1. The "Activity Not Known" category includes sources containing radionuclides listed in Appendix C for which the activity was not reported. Therefore, the sources were not included in Categories 1 through 5.
2. The "Nuclide Not Known" category includes those sources for which the radionuclide was not reported. Thus, the sources were not included in Categories 1 through 5 or Other.
3. The "Other" category includes sources containing radionuclides not included in Appendix C.
4. Events involving a larger number of sources are sometimes entered as a single source with an aggregate activity (for example, the loss of a container of brachytherapy seeds may be entered as a single source with a total combined activity).

5. Events involving the loss/theft of multiple sources may involve the recovery of only some of the sources and are entered as being partially recovered (rather than marking each source individually). The Category 1 through 3 "not recovered" source counts were corrected for the "partially recovered" source events.

Tables 3 and 4 provide more detail regarding the 10-year and current year "not-recovered" data highlighted in Table 2 in yellow and green, respectively. Table 3 displays radionuclide data pertaining to the IAEA Category 1 through 3 sources lost during the 10-year period that have not yet been recovered. The Decayed Activity values are conservative estimates in that the values are typically decayed from the loss date instead of the manufacturer's assay date. As a result, the actual decayed activities (based on the manufacturer's assay date) are likely less than the estimates. Table 4 is similar to Table 3, but limited to the current year.

Table 3. Summary of IAEA Category 1-3 Sources Not Recovered (FY06-15)

Radionuclide	Half-life[1]	Number of Sources Not Recovered[2,3]	Total Activity (Ci)	Total Decayed Activity (Ci)[4]	Total Decayed Activity IAEA Category
Am-Be	432.7 years	1	3.0	3.0	3
Ir-192	73.83 days	2	40.7	0.0	5
Pu-238	87.7 years	1	2.5	2.4	3
Total		**4**	**46.2**	**5.4**	**3**

Notes:

1. Half-life values from the Chart of the Nuclides, 16th Edition.
2. Events involving a larger number of sources are sometimes entered as a single source with an aggregate activity (for example, the loss of a container of brachytherapy seeds may be entered as a single source with a total combined activity).
3. Events involving the loss/theft of multiple sources may involve the recovery of only some of the sources and are entered as being partially recovered (rather than marking each source individually). The source counts were corrected for the "partially recovered" source events.
4. The source activities were decayed from the event date to 1/13/2016 (data download date).

Table 4. Summary of IAEA Category 1-3 Sources Not Recovered (FY15)

Radionuclide	Half-life[1]	Number of Sources Not Recovered[2,3]	Total Activity (Ci)	Total Decayed Activity (Ci)[4]	Total Decayed Activity IAEA Category
Am-Be	432.7 years	1	3.0	3.0	3
Total		**1**	**3.0**	**3.0**	**3**

Notes:

1. Half-life values from the Chart of the Nuclides, 16th Edition.
2. Events involving a larger number of sources are sometimes entered as a single source with an aggregate activity (for example, the loss of a container of brachytherapy seeds may be entered as a single source with a total combined activity).

3. Events involving the loss/theft of multiple sources may involve the recovery of only some of the sources and are entered as being partially recovered (rather than marking each source individually). The source counts were corrected for the "partially recovered" source events.
4. The source activities were decayed from the event date to 1/13/2016 (data download date).

2.2.2 FY15 Data

Two hundred twenty-four LAS events occurred in FY15, 15 of which involved irretrievable well logging sources. Excluding the irretrievable well logging sources, approximately 293 sources were lost/abandoned/stolen, 133 of which have not been recovered. Of the 293 lost sources, two were Category 1, nine were Category 2, and four were Category 3 sources; all of which were recovered except one Category 3 source.

Fourteen of the FY15 LAS events were considered significant (involved Category 1-3 sources). Note that regardless of IAEA category, events involving irretrievable well logging sources are not considered significant.

Significant Events - Category 1 Source Events

Item Number 150091 - A radioactive source manufacturer reported that a shipment of Ir-192 wafers/disks was delivered to the wrong address by a common carrier on 2/9/2015. Three containers of Ir-192 wafers/disks (to be assembled into sealed sources) were being shipped from the manufacturer's Burlington, Massachusetts, facility. Each container held IAEA Category 1 quantities of Ir-192. Two containers were destined for South Korea and one for the manufacturer's Baton Rouge, Louisiana, facility. The label on one of the South Korean containers was either not legible or missing and that container was incorrectly bound to the container going to Baton Rouge by the common carrier at their Memphis, Tennessee, hub. The incorrectly bound container held 432.16 TBq (11,680 Ci) of Ir-192 and was delivered to the Baton Rouge facility. The common carrier was notified of the incorrect delivery. The common carrier was scheduled to pick up the container on 2/10/2015 and forward it to South Korea.

Item Number 150098 - A radioactive source manufacturer reported the loss and recovery of six packages that contained a total of 2,701 TBq (73,000 Ci) of Ir-192. Two of the packages each contained four special form capsules and the other four packages each contained three special form capsules. All of the special form capsules contained Ir-192 wafers/disks. The manufacturer was notified on 2/13/2015 by the common carrier that they had initiated a trace on the lost packages. The shipment originated from the Netherlands and was intended for Burlington, Massachusetts. The packages were located by the common carrier at their Memphis, Tennessee, facility on 2/13/2015. The packages were then delivered to the manufacturer on 2/16/2015.

Significant Events - Category 2 Source Events

Item Number 140728 - A radiography services company reported the loss and recovery of a radiography exposure device that contained a 1.7 TBq (46 Ci) Ir-192 source. Operations were being performed at a gas pipeline compressor station near Perkins, Oklahoma. Radiographers unintentionally left the exposure device at the site at about 1:00 a.m. on 11/6/2014. The client's inspector found the device at about 7:30 a.m. that morning. The client contacted the radiography services company, who recovered the exposure device and source. There was no evidence of tampering. The Oklahoma Department of Environmental Quality investigated the incident. Corrective actions included providing additional training to personnel.

Item Number 140740 - A radiography services company reported the loss and recovery of a radiography exposure device, which contained a 1.41 TBq (38 Ci) Ir-192 source. The radiography services company was notified by local law enforcement on 11/12/2014 that the radiography exposure device had been found on the side of the road, approximately three miles from the company's facility. The company determined that the device had fallen from one of their trucks en route to a temporary job site. The device had not been secured inside the truck, but had been left on the tailgate due to miscommunication. The company retrieved the device and there was no apparent damage. They estimated that the device was out

of their possession for approximately 2.5 hours. The device had been locked and the keys were not with it while lost. Corrective actions included additional training for involved personnel.

Item Number 150038 - A radioactive source manufacturer reported two missing Ir-192 sources that contained 3.8036 and 3.7999 TBq (102.8 and 102.7 Ci), respectively. They had shipped the sources in a source changer to a customer. The customer notified the manufacturer on 1/13/2015 that the shipment had not arrived as expected. The customer contacted the common carrier and was told that the shipment could not be located. A trace of the shipment was initiated. The carrier believed that the shipment was in the U.S. Postal Service facility in Charleston, South Carolina. The source manufacturer was later notified by the carrier that the shipment had been located in the carrier's Memphis, Tennessee, hub. The shipment had no indication of tampering and was shipped to the customer. The carrier will provide additional training to their personnel.

Item Number 150243 - A radiography services company reported the loss and recovery of a radiographic exposure device that contained a 2.92 TBq (79 Ci) Ir-192 source. On 4/6/2015, an assistant radiographer was distracted and left the device on the truck's tailgate prior to traveling to a temporary jobsite. The crew passed the jobsite and made a U-turn, causing the device to fall from the truck. After arriving at the jobsite and beginning to setup for the job, the radiographers discovered that the device was missing. Retracing their route failed to locate the device, because it had already been recovered. A private citizen had discovered the device in some weeds on the side of the road in the area where the radiographer's had made their U-turn. The private citizen contacted the New Iberia Fire Department. Based on documentation with the device, the Fire Department contacted the radiography services company. The company's RSO responded to the location, surveyed the device, and returned it to the company's facility. Involved personnel were reprimanded and required to complete additional training. In addition, a procedure was generated allowing only radiographers to remove devices from vaults and secure them inside transport vehicles.

Item Number 150332 - A radiography services company reported leaving a radiography exposure device, which contained a 1.26 TBq (34 Ci) Ir-192 source, unattended while in a company radiography truck parked at the Baton Rouge Metro Airport in Louisiana. A radiographer left the device in the truck and boarded a plane on 6/8/2015, which departed at 7:00 am. The individual that was to retrieve the truck did not arrive at the airport until 8:40 am. The alarm system was set off and the alarming device was unmanned for approximately two hours.

Item Number 150362 - A radiography services company reported the loss and recovery of a radiography exposure device that contained a 1.78 TBq (48.2 Ci) Ir-192 source. The device was intended to be loaded into a radiography truck and transported to a temporary jobsite. However, the device was left on the bumper of the truck and not secured in the vault/overpack. The radiography crew left their facility and went from Highway 30 to U.S. East Interstate 10 and had been on the Interstate for five miles before realizing the error. They stopped and discovered that the device was missing at 0830 on 6/25/2015. The Louisiana State Police were notified. The Louisiana Department of Environmental Quality was notified and dispatched personnel. The media was notified and alerted the public. The Department and the radiography services company searched for the device. The device was recovered at about 1900 approximately 1.5 miles away on LA-61, east of U.S. East I-10. It was in a wet, muddy, ditch area off the side of the road. A health and safety survey was conducted and the shielding appeared intact. The exposure device was loaded into another company vehicle and returned to their facility. Leak tests revealed negative results.

Item Number 150439 - A radiography services company reported that a radiography truck containing a radiography exposure device with a 3.7 TBq (100 Ci) Ir-192 source was stolen from a convenience store on 7/30/2015 in Tulsa, Oklahoma. The crew went inside the store and left the keys in the vehicle. Surveillance video from the store showed a dark blue truck pull up next to the radiography truck, a person got out of the blue truck and into the radiography truck, then both were driven away. The radiography

services company used the truck's global positioning system to locate it and contacted police. A company employee traveled to the truck's location and observed two men removing equipment, including the radiography exposure device, from the truck. The two men fled when he approached. The device was locked when it was recovered and radiation surveys confirmed that the source was in its shielded position.

Item Number 150587 - A biotechnology company abandoned an irradiator in a facility in Philadelphia. The irradiator contained 15.24 TBq (411.91 Ci) of Cs-137. The company was one year behind on their rent payment and was about to be evicted from the property. The facility landlord had no knowledge of the irradiator, entered the building on 5/27/2015 and began changing all of the locks, giving himself access to the irradiator. The alarms were triggered and the local law enforcement agency responded to the facility. The Pennsylvania Department of Environmental Protection was contacted and performed an emergency inspection. They confirmed that the Cs-137 source was present in the irradiator. The Department allowed the company to retain their license, provided that they settle with the landlord and secure a letter of credit as financial assurance. The company modified their procedures to prevent future occurrence. This event was classified as an LAS and OTH event.

Significant Events - Category 3 Source Events

Item Number 140603 - A medical center reported that a deceased patient was buried with his pacemaker intact in South Paris, Maine. The pacemaker contained 103.6 GBq (2.8 Ci) of Pu-238. The medical center discovered the incident during a routine quarterly check of the patient. It was determined that when the patient died, neither the cardiologist nor the funeral director removed the pacemaker. The exact location of the pacemaker is known. NRC indicated that the body would not need to be exhumed. Communications between the medical center, New Jersey Department of Environmental Protection, and NRC indicated that there were no possible corrective actions to be taken.

Item Number 150440 - A hospital reported that a 370 GBq (10 Ci) Ir-192 source was delivered to the wrong address. The source was in an unsecured location for approximately 23.5 hours. The source had been delivered by common carrier at 0900 on 7/29/2015 to a clinic of similar name. The source was subsequently delivered to the hospital at 0830 on 7/30/2015. The hospital's actions to prevent recurrence included reviewing procedures, obtaining photos of packages containing radioactive material, and retraining personnel on receipt procedures. The Arkansas Department of Health investigated the incident.

Item Number 150510 - A radioactive source distributer reported that a 429.2 GBq (11.6 Ci) Ir-192 source was delivered to the wrong address. The source was intended for a hospital in Washington, D.C., and was shipped on 8/31/2015. However, the common carrier delivered the source to a different hospital in Washington, D.C., on 9/2/2015. The common carrier was notified of the delivery error, took possession of the source on 9/3/2015, and delivered it to the correct address that day. The source shielding and shipping container were intact during the incident; it was not damaged or opened until it reached the correct final destination.

Item Number 150570 - A well logging services company reported the loss and recovery of a 111 GBq (3 Ci) Am-Be source. The company RSO last verified possession of the source on 6/2/2015 during a leak test. The company believes that the source container was dislodged from a logging rig while returning from a jobsite in Decatur, Illinois. Preliminary investigation indicated personnel failed to properly secure the container to the rig on about 9/9/2015. It was not until 10/15/2015 that the source was discovered to be missing. The source had been secured and locked within the container at the time of loss. The company conducted visual surveys along the rig’s travel route without success. The Illinois Emergency Management Agency dispatched teams with radiation detectors to traverse the route. Local law enforcement, scrap yards in the area, and officials in 13 surrounding counties were informed. A press release was issued to media outlets. A monetary reward was offered for useful information or recovery of the source. Corrective actions included obtaining new equipment, developing a new procedure, and providing personnel with additional training and supervision. On 3/4/2016, the company reported that the

source was returned intact by a citizen. The source was still locked in its transport case and had not been tampered with. A swipe test of the source revealed negative results.

Events of Interest

Item Number 150203 - A load of scrap metal set off the radiation monitor alarms at a recycling facility on 4/10/2015. The source of radiation was shielded by scrap metal, but the exposure rate was stated to be 1 µSv/hour (100 µrem/hour) in a background of 0.5 µSv/hour (50 µrem/hour). The load was returned to the originating facility. The Massachusetts Radiation Control Program responded to the facility to investigate. Using a multi-channel analyzer, they identified a metal object that contained Ra-226 with a contact exposure rate of 1.13 mSv/hour (113 mrem/hour). The object was calculated to contain an activity of 555 kBq (15 µCi). It measured 7.5 by 2.5 by 2.5 mm and had no identifying markings. The object was placed into a plastic bag, inside a container, and segregated. A waste broker removed the source from the facility on 11/19/2015 for proper disposal.

Item Number 150318 - Material in a waste container set off the radiation monitor alarms at a landfill on 4/13/2015. The radionuclide was identified as Cs-137. The Texas Department of State Health Services performed an onsite investigation and confirmed the material to be dirt/mud contaminated with Cs-137. The contaminated material was isolated. Department staff drove the route traveled by the collection vehicle and performed radiation surveys in an attempt to locate the source. Radiation was identified in a drainage ditch along the side of the road near the intersection of Sunbury and Bacher Streets in Houston, Texas. Initial surface readings obtained in the ditch ranged from 430 µR/hour to 16 mR/hour. Surveys also indicated additional activity as far as 70 feet from the hottest spot. The ditch was closed by the city. A contractor was hired and started remediation of the area on 5/21/2015. During remediation, radiation surveys revealed up to 1 R/hour, at about three feet from the original surface of the ditch. Soil was removed to a maximum depth of 14 feet. The contractor used a low pressure water blaster to excavate the area. The remediated water was collected in barrels. The owner of the Cs-137 could not be determined. This event was classified as an EQP, LAS, and RLM event.

Item Number 150361 - A water treatment company reported that an x-ray fluorescence analyzer was damaged and the associated 370 MBq (10 mCi) Am-241 source was lost. The analyzer could not be found during an inspection conducted on 4/30/2015. It was located on 5/15/2015, but the probe containing the Am-241 source was missing. The source was declared to be lost on 6/4/2014 following repeated searches for the probe. It was stated that a turnover in staff caused the oversite. The device had been at the facility since 1989 and employees had not remembered using it in years. The company will be more aware of devices containing radioactive material in the future. This event was classified as an EQP and LAS event.

Item Number 150367 - A university received a shipment from a radiographic equipment manufacturer on 6/29/2015 that was believed to contain a 65.49 GBq (1.77 Ci) Yb-169 source, a 64.38 GBq (1.74 Ci) Yb-169 source, and a 7.66 GBq (207 mCi) Se-75 source. However, the package arrived empty. The Yellow II labeled cardboard package had been visibly damaged and resealed with clear shipping tape. Radiation surveys identified background results. The common carrier, manufacturer, and various government agencies were contacted. The three sources were described as titanium capsules approximately 5 mm long and 1 mm in diameter. Each source was in a labeled 1.5 inch glass vial with a teal-colored screw-on cap. The Massachusetts Department of Public Health conducted an investigation at the university on 6/30/2015. They also performed radiation surveys at three of the common carrier's facilities on 7/1/2015. No sources were found and all radiation readings were at background. On 7/10/2015, radiation monitors alarmed at a Memphis, Tennessee, landfill. A load of trash from the common carrier was identified as radioactive. The load of trash was returned to the common carrier and Tennessee Division of Radiological Health staff responded. The material was placed into a five-gallon metal bucket. Radiation surveys of the bucket revealed approximately 200 mR/hour on contact, with between 80 and 90 mR/hour at one meter. The contents were determined to contain the missing Se-75 source as well as pieces of the subject package; the Yb-169 sources were still missing. It was concluded that the shipping package was

damaged and contents lost at the common carrier's transportation hub in Memphis, Tennessee. The common carrier performed worker retraining to prevent recurrence.

Item Number 150474 - Members of the public found radioactive material on 8/11/2015 while cleaning out a warehouse belonging to a college. They came across an unusually heavy box. They opened the box and found a collection of items including a lead pig which was labeled "HOT 4 tubes RADIUM 1 broken." While handling the pig, the lid came open and an object described as a metal rod approximately 1.25 inches by 3 inches fell out. One individual picked up the rod and handled it for a few minutes before they noticed a "RADIOACTIVE" label on the side of the pig. They replaced the object in the pig and notified college personnel. The individual that handled the rod was wearing leather work gloves. The college does not possess a radioactive material license. The individual who handled the rod sought medical attention, complaining of nausea, dizziness, pain in his hands, and blistering on his feet. The Oklahoma Department of Environmental Quality conducted a reactive inspection of the facility on 8/17/2015. Radiation surveys of the facility found no contamination. Wipe tests of various objects and areas were collected for analysis. Radiation readings on the exterior of the pig ranged from 1.5 to 3.5 mR/hour. Readings were 70 mR/hour directly above the pig's open mouth. A variety of other sealed and unsealed sources were also found, many dating from the late 1950s. The college secured the sealed and unsealed sources and will arrange for their disposal as soon as possible. On 8/18/2015, it was stated that the individual who handled the source had been diagnosed with a reaction to mold exposure, given a cortisone injection, and was doing much better. On 8/26/2015, wipes revealed the box and contents were contaminated with Ra-226. Wipes in other areas in the basement revealed no removable contamination. The sealed and unsealed sources were picked up by a licensed waste broker on 11/10/2015.

Item Number 150480 - A sanitation truck carrying a load of garbage was stopped by local police in Union City, New Jersey, on 8/15/2015. The officer's radiation monitor alarmed as he approached the truck. Police initially identified the radionuclide as Ra-226. New Jersey Department of Environmental Protection personnel responded and confirmed Ra-226. An exposure rate of 60 mR/hour was detected on contact with the truck. The activity was estimated at 370 MBq (10 mCi). A consultant was able to reduce the surface exposure rate below 50 mR/hour so that a Department of Transportation Special Permit could be issued. The truck was moved to a sanitation facility in Jersey City, New Jersey, on 8/17/2015. A contractor sorted the waste and found a small Ra-226 source. The source was not labeled. It was shielded and secured at the site pending disposal. The source was removed from the site by a licensed waste broker on 8/25/2015.

2.2.3 Events Recently Added to NMED That Occurred Prior to FY15

Thirty-five LAS events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. One of these events was considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events - Category 1 Source Events
None

Significant Events - Category 2 Source Events
None

Significant Events - Category 3 Source Events
Item Number 150395 - A hospital reported the temporary loss of control of a 386.28 GBq (10.44 Ci) Ir-192 source. The source was ordered to replace the existing source in a high dose rate remote afterloader unit. The RSO was concerned that the source would be delivered on 9/2/2013 (Monday), which was the Labor Day holiday, when no authorized user would be present to receive the source. The RSO contacted the source provider on 8/30/2013 (Friday) and was assured that the source would be delivered on 9/3/2013 (Tuesday). However, the source was actually delivered to the loading dock at 1008 on

8/31/2013 (Saturday). The package triggered a radiation monitor alarm, but workers on duty were unaware of the purpose or cause of the alarm, as well as their responsibilities when the alarm sounded. Attempts to contact the RSO were eventually made. At approximately 1430, the package was moved into a locked area, which silenced the alarm. When the RSO arrived at approximately 1630, the source of the alarm was assumed to be a load of hot trash in the dumpster. When surveys of the dumpster were negative, no further investigation was performed. On 9/3/2013 (Tuesday), the RSO retrieved the package and noted that it had been delivered on 8/31/2013 (Saturday). The RSO contacted NRC Region I by telephone to report the temporary loss of control of the source. Corrective actions included training all personnel involved regarding the proper procedures for radioactive material receipt and security. A formal policy was established with the source provider to ensure that packages are delivered during normal business hours (no holidays).

Events of Interest

Item Number 150228 - A badly damaged moisture/density gauge was found in a load of scrap metal. On 9/4/2014, the California Highway Patrol notified the California Radiologic Health Branch (CRHB) that a truck had triggered a radiation alarm. The scrap metal originated at a recycling facility in Phoenix, Arizona. The driver was instructed to take the material to its home destination in Carson, California. A CRHB inspector arrived at the facility that same day. Using a Bicron MicroRem meter, net exposure rates were 30 µSv/hr (3,000 µrem/hr) at the surface of the scrap metal container, with 4.5 µSv/hr (450 µrem/hour) at one foot, and 1.7.5 µSv/hr (175 µrem/hr) at three feet (background was 0.04 µSv/hr or 4 µrem/hr). Using a Canberra Inspector 1000 multi-channel analyzer, the radionuclide was identified as Cs-137. The material was transferred to a scrap metal facility in Los Angeles, California, where it was dumped and sorted. A radioactive waste services company was contracted to identify the radioactive material. On 9/11/2014, they reported that the radioactive material consisted of a damaged moisture/density gauge (Troxler model 3450, serial #00533) that contained a 1.48 GBq (40 mCi) Am-Be source and a 0.3 GBq (8 mCi) Cs-137 source. CRHB placed the gauge in their radioactive storage location in Baldwin Park, California. CRHB was able to identify the original owner of the gauge, who had reported the gauge as stolen on 6/14/2014 (see NMED Item Number 140324). The damaged gauge was removed from the California storage facility and transferred to a licensed gauge service center on 3/20/2015. Leak testing revealed that neither radioactive source was leaking or damaged. The gauge manufacturer approved return of the gauge to them for proper disposal. This event was classified as an EQP and LAS event.

Item Number 150379 - A medical center reported that a patient potentially received 51.75 cSv (rem) to the skin during a low dose rate brachytherapy source implant procedure performed on 6/14/2013. Catheters in the patient's tongue were loaded with strands of Ir-192 sources. Each catheter contained a strand of five sources. Each source contained an activity of 41.44 MBq (1.12 mCi). A physician checked on the patient and ensured that all sources were in place at 0730 on 6/14/2013. Nursing staff changed the patient's bedding at 1000. A radiation oncologist checked on the patient at 1230 and determined that one strand of sources was missing. Personnel exited the patient's room and health physics personnel were notified. Radiation surveys identified radioactivity in the linen basket and the strand of sources was recovered at 1245. The strand was reinserted into the patient's catheter and the patient's tongue received the intended dose. However, during a Kentucky Department of Radiation Control inspection, staff concluded that the missing strand of sources could have caused a worst-case skin exposure to the patient of 51.75 cSv (rem). The patient received follow-up visits following the event and no effects were noted. The patient was not informed of the medical event. This event was classified as an LAS and MED event.

2.3 Medical

2.3.1 Ten-Year Data

Figure 3 displays the annual number and trend of MED events that occurred during the 10-year period. The trend analysis determined that the Agreement State-regulated events represent a statistically significant increasing trend (indicated by the trend line). However, the NRC-regulated and Total events do not represent statistically significant trends (indicated by the absence of trend lines). Therefore, variations within the NRC-regulated and Total values represent random fluctuation around the average of the data.

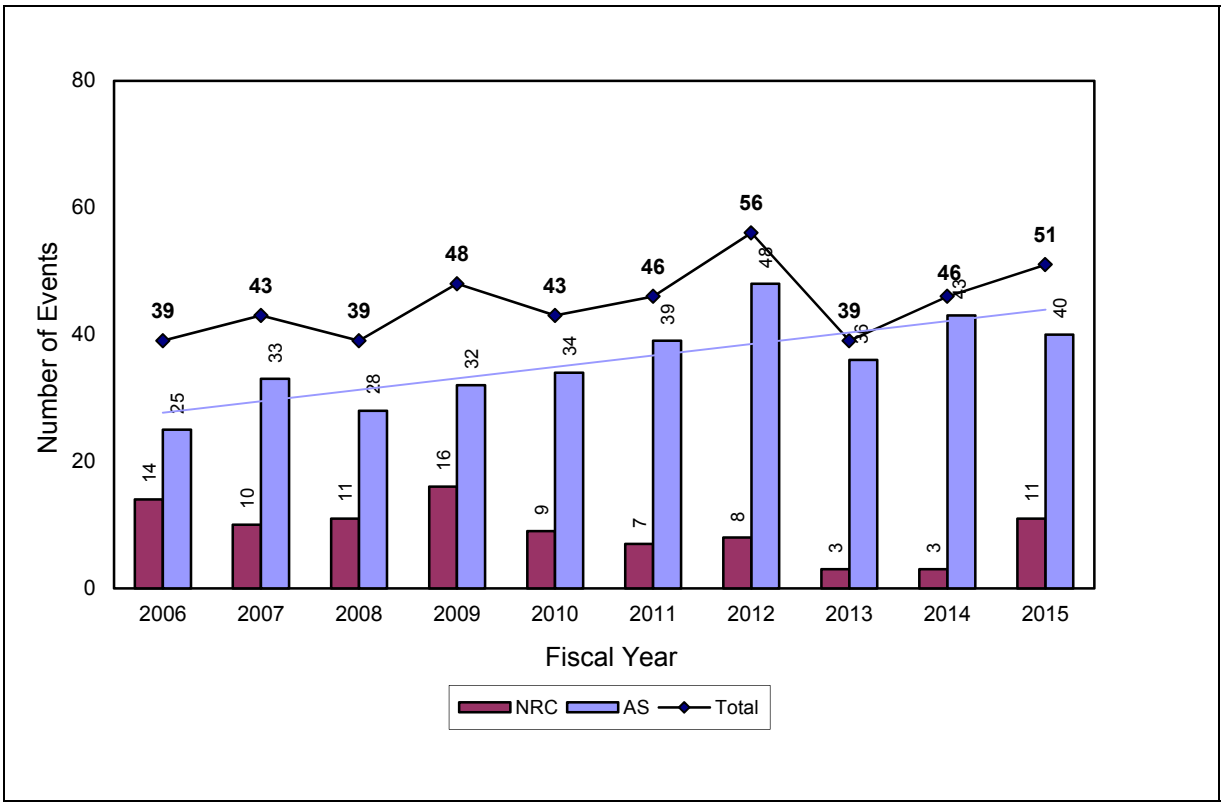

Figure 3. Medical Events (450 total)

Table 5 lists the number of MED events that were classified as Abnormal Occurrences (AOs) in NUREG-0090, *Report to Congress on Abnormal Occurrences*. Table 5 also includes events involving doses to an embryo/fetus or a nursing child (reportable per 10 CFR 35.3047). By definition, these events are not medical events (reportable per 10 CFR 35.3045) and are captured in NMED as an "Other" event. However, they are included here for reference.

Table 5. Medical and Embryo/Fetus or Nursing Child AO Events

	Fiscal Year										
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total[1]**
Medical	7	11	12	15	12	14	13	7	11	11	**113**
Embryo[2]	3	2	2	2	2	1	1	2	1	1	**17**
Total	**10**	**13**	**14**	**17**	**14**	**15**	**14**	**9**	**12**	**12**	**130**

Notes:

1. Events are marked as potential AOs until they complete the NRC's formal AO determination process and are reported in NUREG-0090. Potential AOs are included in this table.
2. Includes doses to an embryo/fetus or a nursing child reportable per 10 CFR 35.3047.

For this report, events classified as AOs (or potential AOs) are considered significant. Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

2.3.2 FY15 Data

Fifty-one MED events occurred in FY15, 11 of which were considered significant.

Significant Events - AOs or Potential AOs

Item Number 140803 - A patient only received 3.6% of the prescribed dose during a prostate seed implant procedure performed on 12/10/2014. The procedure was performed under ultrasound guidance and real time treatment planning. The patient was being treated for a boost therapy following external beam treatment. The incident was identified during a post-implant computed tomography scan performed on 12/10/2014. The prostate was prescribed to receive 53 I-125 brachytherapy seeds containing a total activity of 705.96 MBq (19.08 mCi); each seed contained an activity of 13.32 MBq (360 μCi). However, all 53 seeds were inadvertently implanted into the patient's penile bulb. The prescribed D90 dose to the prostate was 16,404 cGy (rad), but the prostate only received 590 cGy (rad). Dose to the unintended area was approximately 10,800 cGy (rad). The physician and patient were informed of the discrepancy on 12/11/2014. A medical determination was made to not remove the seeds due to the difficulty of removal. The medical center monitored the patient for several weeks to determine whether damage to the urethra had occurred. The Maryland Department of the Environment Radiological Health Program performed a reactive inspection on 12/19/2014. The medical center determined that prior to patient treatment, the ultrasound unit had been serviced by the vendor. Following service, some of the calibration settings were changed (i.e. gain controls). The medical center failed to identify those changes and conducted the implant procedure using an ultrasound unit that was not calibrated accurately calibrated. The medical center implemented procedures to assure efficacy of the ultrasound unit after servicing and prior to use.

Item Number 150007 - A patient prescribed to receive 1.11 GBq (30 mCi) of I-131 for a dose of 8,000 cGy (rad) for thyroid ablation was actually administered 5.28 GBq (142.6 mCi) of I-131 for a dose of 37,391 cGy (rad) on 12/17/2014. The wrong vial was selected from the dosage cart due to patient misidentification. The patient and prescribing physician were informed of the error. No adverse health effects are expected due to this event. Corrective actions included revising the policy for patient identification and the written directive for radiopharmaceutical administration on 12/17/2014. Personnel will also receive additional training and supervision.

Item Number 150096 - A patient receiving radiation treatments following surgical removal of a breast tumor, actually received 10 high dose rate (HDR) fractions to the catheter entrance site, which was 4 cm from the intended site. Each fraction was prescribed to deliver 340 cGy (rad) using a remote HDR unit and 257.15 GBq (6.95 Ci) Ir-192 source. The medical center initially identified the incident due to redness, pain, and swelling observed near the patient's catheter insertion site. It was determined that the intended dose had been delivered with the connector end of the applicator interface as the reference location, instead of the tip of the applicator. The fractions had been completed using a strut adjusted volume implant applicator and followed an accelerated partial breast treatment regime. The catheter insertion site was estimated to have received 13,000 cGy (rad). The patient received medical treatment for the damage tissue, but it would not heal. As a result, a mastectomy was performed. The Illinois Emergency Management Agency conducted an investigation. The cause of the error was determined to be that the dwell positions within the applicator were not accurately reconstructed in the treatment planning computer. A lack of familiarity with the planning software, difficulty identifying the starting

position for multiple catheter HDR treatments within the system, and failure to confirm the planning software accurately reflected the intended treatment were contributing factors. Corrective actions included modifying the treatment planning systems, implementing additional quality assurance procedures/checklists, and involving additional personnel to verify plans prior to patient treatment.

Item Number 150131 - A therapy misadministration occurred involving a 57-year-old patient receiving treatment for endometrial cancer. The treatment involved the use of a remote high dose rate afterloader and a 169.83 GBq (4.59 Ci) Ir-192 source. The patient was prescribed three fractions of 700 cGy (rad) each performed on 1/7, 1/14, and 1/19/2015. The patient subsequently complained of bilateral labial itch, dryness, and tingling, and was referred to a dermatologist who identified a radiation reaction. Review of the films taken to confirm placement of the Ir-192 source revealed that the source was placed inferior to the treatment site and exterior to the opening of the vagina. Treatment staff thought the film showed proper placement but due to the patient's obesity, the film quality was poor. The resulting dose to the intended treatment volume was very minimal. However, unintended areas (outer vaginal mucosa and upper thigh) received the entire 2,100 cGy (rad). The patient will be evaluated for skin and mucosa thickening, potential scarring, and possible urinary tract and rectal issues.

Item Number 150140 - A medical center reported eight medical events involving a gamma knife unit that contained 244.2 TBq (6,600 Ci) of Co-60. The patients were being treated for acoustic neuromas and metastatic tumors in the brain. All eight patients received their prescribed doses, ranging from 700 to 2,490 cGy (rad), to the wrong location due to misalignment of the patient positioning system. This misalignment occurred during maintenance of the unit between 12/13/2014 and 1/1/2015 by the manufacturer, with resulted in the patient positioning system being off-target by 1.87 mm. The eight patient treatments were performed between 1/7 and 2/12/2015. All of the patients and referring physicians were notified. The effects to the patients are still being determined. The cause of the misalignment of the patient positioning system was the failure to use the correct service procedures during maintenance. Corrective actions include the development of a new set of tests to verify patient positioning. This event was classified as an EQP and MED event.

Item Number 150317 - A patient received 873.94 MBq (23.62 mCi) of Y-90 microspheres to the wrong lobe of the liver on 5/29/2015. The prescribed dose was 27 mCi of Y-90 to the left lobe of the liver (Segment 4) for a dose of 12,530 cGy (rad). However, the microspheres were unintentionally administered to the right lobe of the liver (segments 1, 5, 6, 7, and 8) for a dose of 13,000 cGy (rad). The left lobe (Segment 4) only received 4,370 cGy (rad). The medical center was planning on treating the right lobe of the liver in the future. The patient and referring physician were notified of the event on 5/29/2015. The Minnesota Department of Health investigated the incident. The cause of the event was determined to be injecting the microspheres into the wrong artery. A contributing factor was the patient’s small and similarly appearing vessels. Microspheres will be administered to segment 4 in a future treatment. The medical center will implement a new procedure to prevent recurrence.

Item Number 150326 - A patient received 1.3 GBq (35.2 mCi) of Y-90 microspheres to the wrong site during treatment of the liver for metastatic cancer lesions on 6/2/2015. The infusion catheter was placed into the patient’s renal artery, instead of the hepatic artery. This was the facility’s first patient to undergo this treatment modality and the manufacturer’s representative was present during the procedure. The patient was informed of the error and consented to a second dose of Y-90 microspheres, which was performed successfully. The patient was held overnight and routine collection and measurement of urine was performed prior to being discharged into the sewer system. Radioactivity was confirmed in the urine. No other contamination was noted in the patient’s specially prepared room. The patient was discharged the next day (6/3/2015) and will receive follow-up visits with the urologist and radiologist. The dose to the patient’s liver was approximately 65 Gy (6,500 rad) from the second treatment. The dose to the patient’s kidney from the misadministration was calculated by the manufacturer to be 1,345 Gy (134,500 rad). Corrective actions included developing a formal written checklist to be completed prior to each patient administration, having additional mapping imagines available for placement of the catheter, and a

review of the catheter placement by a second physician prior to administration. The Illinois Emergency Management Agency is investigating the incident.

Item Number 150408 - A patient received 288.23 MBq (7.79 mCi) of Y-90 microspheres to the small bowel on 7/14/2015. The patient was prescribed to receive an activity of 758.5 MBq (20.5 mCi) to the right lobe of the liver for a dose of 7,800 cGy (rad). However, during administration the physician felt that the microspheres were not traveling to the liver and discontinued treatment. The small bowel received a dose of 3,600 cGy (rad). The involved physician was also the patient's referring physician. The patient was notified of the event. The Ohio Bureau of Radiation Protection sent an inspector to the medical center to investigate. The cause was determined to be inattention to detail. Corrective actions included procedure modifications and providing additional training to personnel.

Item Number 150420 - A dose administered to a patient treated for skin cancer on the nose exceeded the prescribed maximum radiation dose by more than 50%. The patient was treated using a high dose rate brachytherapy unit and a 370 GBq (10 Ci) Ir-192 source. The physician's written directive specified a dose to the tumor volume and a maximum tumor dose of 130% of that prescribed. The total dose was delivered in eight fractions using a skin applicator from 6/9 to 7/2/2015. The prescribed dose was 500 cGy/fraction (rad/fraction) for a total dose of 4,000 cGy (rad), with a maximum dose of 650 cGy/fraction (rad/fraction) for a total maximum dose of 5,200 cGy (rad). On a follow-up exam, the patient's skin reaction was more drastic than anticipated. The health physics department was asked to review the administered treatment. Results indicated that the tumor volume maximum dose exceeded the prescribed maximum dose of 130%, by more than 50%. The estimated dose received by the patient's target was 950 cGy (rad) for five fractions and 700 cGy (rad) for three fractions, for a total of 6,850 cGy (rad). Therefore, the incident resulted in the patient receiving 71.25% greater than prescribed or 31.73% greater than the maximum dose prescribed in the written directive. The incident occurred due to a deficient treatment plan developed by a junior medical physicist. The plan was reviewed by the authorized medical physicist and the authorized user. The medical center did not have documented procedures for the treatment plan in accordance with the written directive. They will develop, document, and train personnel on specific procedures for the treatment plan.

Item Number 150421 - A medical event occurred during a patient treatment for cancer of the endometrium using a vaginal cylinder applicator. The treatment was delivered in three fractions from 6/8 to 6/17/2015. Equipment included two different high dose rate (HDR) brachytherapy units and two different 370 GBq (10 Ci) Ir-192 sources. The first source and HDR unit were used in the first fraction and the second source and HDR unit were used in the second and third fractions. The three fractions were performed as planned. Each fraction was prescribed to deliver 600 cGy (rad), for a total of 1,800 cGy (rad). However, during a follow-up exam on 7/20/2015, the patient revealed two small sores on the skin of both her upper thighs. Each sore was 0.5 cm wide and 1 cm long. The radiation oncologist believed the marks were consistent with radiation dermatitis. Computer reconstruction of the event revealed that the dose delivered to the patient's skin was 4,000 cGy (rad) at a depth of 0.2 cm. The patient also received 33% less dose to the intended site than prescribed by the written directive. The event occurred because personnel assembled the vaginal cylinder applicator incorrectly. However, it is also possible that the applicator became loose while in the patient. It was determined that the physicist failed to inspect the applicator prior to administration. The medical center will develop, document, and train personnel on this specific procedure. The Georgia Department of Natural Resources performed a reactive inspection on 7/24/2015.

Item Number 150452 - A cervical cancer patient received 900 cGy (rad) instead of the prescribed 300 cGy (rad), during the third of three fractions delivered on 8/5/2015. Equipment used included a tandem and ovoid applicator, a high dose rate brachytherapy unit, and a 185 GBq (5 Ci) Ir-192 source. The patient received 300 cGy (rad) per fraction during her first and second fractions. However, the physicist inadvertently selected and delivered an incorrect treatment plan of 900 cGy (rad) per fraction for the third fraction. The "best practice" step of verifying the treatment plan was skipped. As a result, the patient

received a total dose of 1,500 cGy (rad) during the three fractions instead of the intended 900 cGy (rad). The physicist identified the incident on 8/7/2015 while reviewing the patient's chart. Contributing causal factors included the use of new treatment planning software and poor communication between team members. Corrective actions included standardizing personnel language for patient treatments, adding a step to verify the treatment plan to the existing checklist, investigating equipment safety features and possible manufacturer recall, and starting daily "huddles" within the radiation oncology department. The patient was informed of the event on 8/8/2015.

Events of Interest

Item Number 140599 - A medical event occurred involving a patient treated on 10/15/2014 with a high dose rate (HDR) unit and a 171.72 GBq (4.641 Ci) Ir-192 brachytherapy source. The patient was prescribed to receive 1,800 cGy (rad) during three fractional HDR treatments to the vaginal canal. However, at the conclusion of the third fraction, the physicist entered the room and determined that the cylinder had fallen out of the patient and was lying on the treatment table. The patient was unaware of the incident. The treatment time was for 431.3 seconds. It was concluded that the patient received 1,200 cGy (rad) of the total 1,800 cGy (rad). The cause of the event was determined to be the failure to secure the cylinder in place and the inability to view the cylinder on the camera. Corrective actions included modifying administrative controls by requiring a device to secure the cylinder in place. The Arizona Radiation Regulatory Agency investigated the event.

Item Number 150093 - A therapy misadministration occurred involving a 77-year-old patient receiving treatment for endometrial cancer. The treatment involved the use of a remote high dose rate afterloader and a 331.96 GBq (8.972 Ci) Ir-192 source. The patient was prescribed three fractions of 700 cGy (rad) each to begin on 2/4/15. It was later determined that the vaginal applicator was improperly placed within the organ during the fraction administered on 2/4/2015. Post treatment review of the films taken to confirm placement of the Ir-192 source revealed that the source was placed inferior to the treatment site and exterior to the opening of the vagina. The resulting dose to the intended treatment volume was very minimal. However, unintended areas (outer vaginal mucosa and upper thigh) received the entire fraction of 700 cGy (rad). The patient experienced vaginal burning, but no skin breakdown has been reported. The patient will be evaluated for skin and mucosa thickening, potential scarring, and possible urinary tract and rectal issues.

Item Number 150206 - A patient prescribed a fractional dose of 340 cGy (rad) only received 60 cGy (rad) on 4/13/2015. The patient was receiving brachytherapy treatment to the right breast using an 11-channel strut adjusted volume implant applicator, a high dose rate (HDR) unit, and a 251.16 GBq (6.788 Ci) Ir-192 source. The patient was treated with two channels, but a friction event occurred while sending out the check cable in the third channel and the HDR unit was unable to fully retract the check cable. The medical center stopped the treatment and manually retracted the check cable into the HDR unit. After performing additional tests of the safety check, the check cable became jammed within the HDR unit. The patient and prescribing physician were informed of the event on 4/13/2015. The medical center contacted the vendor and ceased treatments pending repair. The vendor replaced the check cable on 4/14/2015 and returned the HDR unit to service. An inspection of the faulty check cable revealed a fray approximately 0.5 cm behind the welded junction. The interrupted treatment was resumed on 4/14/2015. During NRC's reactive inspection, it was revealed that a prior event involving a damaged check cable was experienced during a routine source exchange on 11/7/2014. During a subsequent source exchange on 5/28/2015, another damaged check cable was identified. The damage on all three check cables was in the same location. Investigation into the cause of the damaged check cables continues. Pending final resolution, the check cable will be examined biweekly for any indications of damage. This event was classified as an EQP and MED event.

Item Number 150412 - A patient scheduled to receive a partial I-125 prostate brachytherapy seed implant procedure with a prescribed dose of 10,700 cGy (rad), actually received a full seed implant procedure resulting in a dose of 16,000 cGy (rad). The total activity prescribed to the patient was 495.8 MBq (13.4

mCi), but the total activity administered was 673.4 MBq (18.2 mCi). The incident occurred on 7/15/2015, was caused by human error, and resulted in the prostate receiving 49.5% greater dose than prescribed. Both the referring physician and patient were notified. The medical center plans to compensate for the error by eliminating the prescribed follow-up 4,500 cGy (rad) external beam therapy. The Pennsylvania Department of Environmental Protection investigated the incident. Corrective actions included modifying procedures to confirm and document the intended implant dose when the implant is scheduled.

Embryo/Fetus or Nursing Child Dose Events - AOs or Potential AOs

Doses to an embryo/fetus or nursing child are reportable per 10 CFR 35.3047. By definition, these events are not medical events (reportable per 10 CFR 35.3045) and are captured in NMED as "Other" events. However, it is appropriate to also discuss these events in this section. One of these events occurred in FY15 and was classified as a potential AO.

Item Number 150027 - A pregnant patient received a thyroid ablation treatment involving 3.6 GBq (97.3 mCi) of I-131 on 12/11/2014. A pregnancy test performed on the day of treatment revealed negative results. On 12/29/2014, the patient suspected that she was pregnant and performed a home pregnancy test, which was positive. The patient reported to a clinic for a serum pregnancy test the same day, which was also positive. On 12/31/2014, the patient notified her endocrinologist that she was pregnant on the day of treatment. The endocrinologist notified the medical center the same day. The gestational age of the embryo/fetus was determined to be between two and four weeks at the time of treatment. The patient was informed of the radiation exposure to her embryo/fetus on 12/31/2014. A medical consultant calculated a dose of 26.6 cGy (rad) to the embryo/fetus, with an effect of either miscarriage or survival without malformation. As of 2/6/2015, an uneventful pregnancy was proceeding. This event was caused by a faulty pregnancy test kit and the patient's lack of awareness that she was pregnant. Corrective actions included revising the patient questionnaire, patient instructions, and radiation safety training program.

2.3.3 Events Recently Added to NMED That Occurred Prior to FY15

Eight MED events and no embryo/fetal dose events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. Two of the MED events were considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events - AOs or Potential AOs

Item Number 140550 - During an NRC inspection at a medical center in February 2012, the inspectors identified four potential medical events involving I-125 seed mesh lung implants where the administered dose was greater than 20% higher than the prescribed dose. On 10/1/2014, the NRC notified the medical center that all four of the potential medical events were determined to be reportable medical events. The implants involved written directives dated 11/17/2006, 6/12/2008, 11/12/2008, and 1/6/2010, involved doses greater than 50 cSv (rem) to an organ or tissue, and resulted in administered doses that were 40%, 74%, 99%, and 114% greater than prescribed, respectively. The medical procedure involved attaching I-125 seeds to a mesh such that the seeds were 1 cm apart from one another. The mesh was subsequently affixed to the lung. The authorized user prescribed about 10,000 cGy (rad) to lung tissue at 5 mm from the center of the I-125 seed mesh plane, presuming that the mesh was flat. However, the mesh ended up curved such that the concave surface of the mesh faced the lung tissue due to re-inflation of the lung after surgery. As a result of the curved mesh, the I-125 sources in the mesh ended up closer to the treatment site, causing the treatment site to receive more dose than prescribed. None of the implants resulted in patient harm or caused excessive dose to an unintended treatment site. The medical center has no plans to implement this treatment protocol in the future.

Item Number 150181 - A patient only received 43% of their prescribed brachytherapy dose to the intended treatment site and received approximately 3,000 cGy (rad) to an unintended site. The incident was discovered during a review of five patient cases performed since August 2013. The patient was prescribed a V95 dose of 3,400 cGy (rad) to a target site in the left breast in ten equal fractions. However, it was determined that a 21 cc tissue area at the breast incision site received approximately 3,000 cGy (rad). Treatment protocols involved a strut adjusted volume implant catheter, a high dose rate afterloader, and a 314.5 GBq (8.5 Ci) Ir-192 source. The patient was treated twice a day for five days between 3/10 and 3/14/2014. The patient returned to the facility on 6/24/2014 with pain and redness at the incision site of the left breast. The cause of damage to the 21 cc tissue area was not attributed to radiation damage at that time. The patient was referred to a surgeon, who excised the affected area during an outpatient procedure. The medical center suspended treatments using the protocol pending full investigation and evaluation of appropriate corrective measures to prevent recurrence. The use of a second physicist to perform an independent evaluation of the treatment plan and the use of a written check-off form are being considered.

Events of Interest

Item Number 150379 - A medical center reported that a patient potentially received 51.75 cSv (rem) to the skin during a low dose rate brachytherapy source implant procedure performed on 6/14/2013. Catheters in the patient's tongue were loaded with strands of Ir-192 sources. Each catheter contained a strand of five sources. Each source contained an activity of 41.44 MBq (1.12 mCi). A physician checked on the patient and ensured that all sources were in place at 0730 on 6/14/2013. Nursing staff changed the patient's bedding at 1000. A radiation oncologist checked on the patient at 1230 and determined that one strand of sources was missing. Personnel exited the patient's room and health physics personnel were notified. Radiation surveys identified radioactivity in the linen basket and the strand of sources was recovered at 1245. The strand was reinserted into the patient's catheter and the patient's tongue received the intended dose. However, during a Kentucky Department of Radiation Control inspection, staff concluded that the missing strand of sources could have caused a worst-case skin exposure to the patient of 51.75 cSv (rem). The patient received follow-up visits following the event and no effects were noted. The patient was not informed of the medical event. This event was classified as an LAS and MED event.

Embryo/Fetus or Nursing Child Dose Events - AOs or Potential AOs

None

2.4 Radiation Overexposure

2.4.1 Ten-Year Data

Figure 4 displays the annual number and trend of EXP events that occurred during the 10-year period. The trend analysis determined that the data does not represent statistically significant trends in the number of events (indicated by the absence of trend lines). Therefore, variations within the annual values represent random fluctuation around the average of the data.

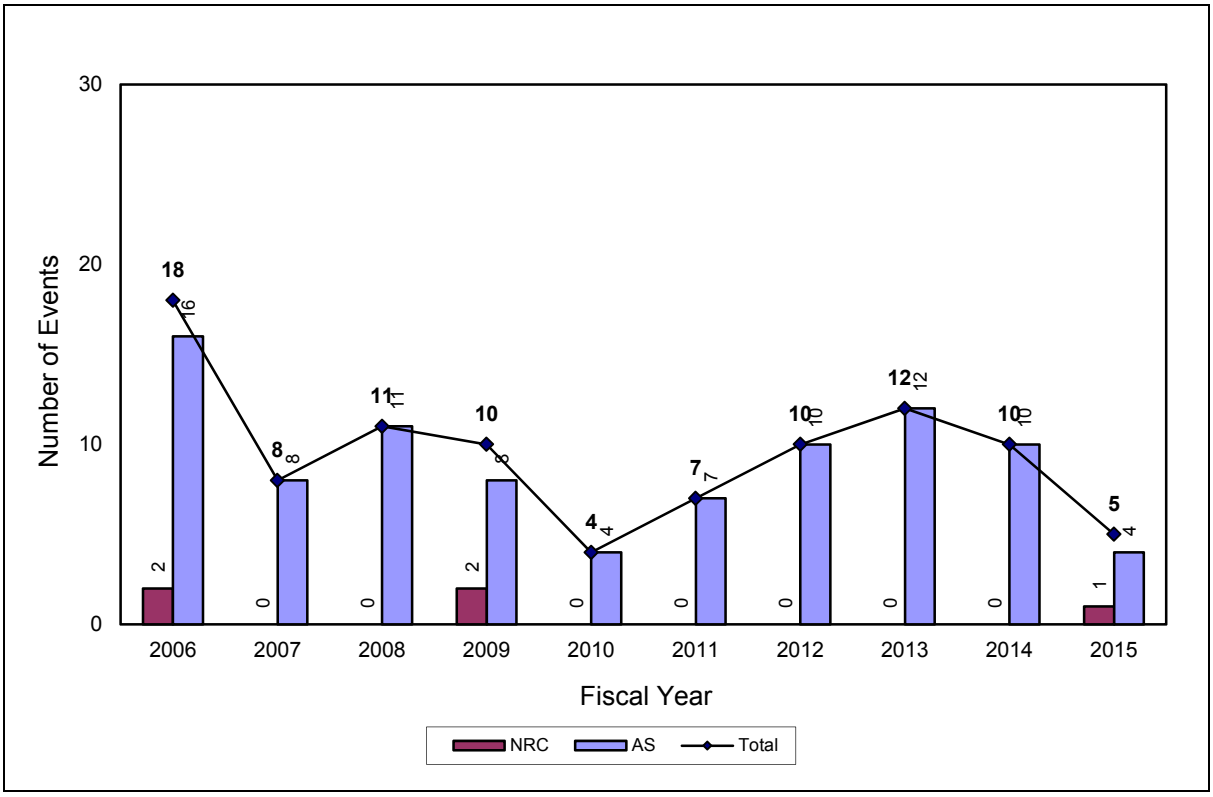

Figure 4. Radiation Overexposure Events (95 total)

The significance of individual EXP events may be determined by the CFR reporting requirement applicable to the event. For example, an event that is required to be immediately reported is typically more significant than an event with a 30-day reporting requirement. For this report, events requiring immediate or 24-hour reporting are considered significant. Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

Table 6 displays the number of events based on the different reporting requirement time categories. Note that each event is counted only once. If an event involved exposures that were reportable in more than one category, the event is counted in only the most restrictive category.

Table 6. EXP Events Classified by CFR Reporting Requirement

	Fiscal Year										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Immediate	1	1	0	0	0	1	1	0	0	0	**4**
24-Hour	3	1	3	1	1	0	4	1	3	3	**20**
30-Day	14	6	8	9	3	6	5	11	7	2	**71**
Total	**18**	**8**	**11**	**10**	**4**	**7**	**10**	**12**	**10**	**5**	**95**

2.4.2 FY15 Data

Five EXP events occurred in FY15, three of which were considered significant.

Significant Events - Immediate Reports
None

Significant Events - Within 24-Hour Reports
Item Number 150049 - A radiographer was overexposed at a refinery in Baton Rouge, Louisiana, on 1/16/2015. The incident involved a 1,410 GBq (38.1 Ci) I-192 source. Following operations, the radiographer attempted to disconnect the guide tube from the exposure device, but it would not disconnect. He determined that the source was not locked in the device and that the locking mechanism indicator was red. A radiographer instructor manipulated the crank assembly a quarter of a turn and fully retracted the source. The exposed radiographer's pocket dosimeter was off scale, but he claimed that his alarming rate meter did not alarm. It was determined that the rate meter alarmed, but it was weak. The radiography company confirmed that the radiographer's whole body exposure was 64 mSv (6.4 rem) and his extremity exposure was 2,060 mGy (206 rad) to his hands. The radiographer was taken to a medical facility for examination. The instructor was retrained in radiation safety practices, lost his instructor status, and has been suspended from radiation work. The exposed radiographer is no longer employed at the company and will not respond to correspondence. The Louisiana Department of Environmental Quality investigated the event. The cause appears to be operator error. As of 1/23/2015, this incident had a final International Nuclear Event Scale rating level of 2. This event was classified as an EQP and EXP event.

Item Number 150156 - A radiography services company reported that personnel overexposures occurred on 3/17/2015. The incident occurred at a power plant during radiography operations using an exposure device that contained a 2.812 TBq (76 Ci) Ir-192 source. A crew of one radiographer and three assistants were completing two exposures lasting 35 seconds, with a set-up time of approximately 15 to 18 minutes. Following the exposures, the radiographer's pocket dosimeter was off-scale (>200 mR), the first assistant's was reading 50 mR, the second assistant's was off-scale, and the third assistant was not wearing any dosimetry. The radiographer and first assistant acknowledged that their alarming rate meters were functioning properly. The second and third assistants were not wearing alarming rate meters. The crew stopped work, notified their RSO (at 2130), and met with the RSO the following morning to discuss the incident. Only the radiographer and first assistant were wearing dosimetry badges. The dosimetry badges were sent for emergency processing. The results revealed exposures of 11.2 and 5 cSv (rem) to the radiographer and first assistant, respectively. The company's preliminary estimate determined that the third assistant (not wearing any dosimetry) may have received a whole body exposure of up to 45 cSv (rem). They determined that the radiation survey meter had an electrical short and did not function properly. The radiography exposure device was checked and functioned properly. The Alabama Department of Public Health visited the power plant, met with plant representatives, and reviewed the area where the incident took place. They also interviewed the company RSO and all involved personnel. The Department determined that the source was outside of the exposure device but not in the guide tube.

The four radiography personnel involved were seen by an occupational physician and submitted blood samples that were sent to the Radiation Emergency Assistance Center/Training Site (REAC/TS) for cytogenic biodosimetry. REAC/TS determined that all four individuals had exposures of less than the minimum threshold of 20 cSv (rem). The primary causes of the incident appear to be failure to use an operable radiation survey meter and failure to follow procedures. Corrective actions included terminating employment of personnel and providing additional training to personnel. Personnel exposures assigned to the four individuals were: 11.232 cSv (rem) to the radiographer, 5 cSv (rem) to the first and second assistants, and 20 cSv (rem) to the third assistant. As of 9/23/2015, this incident had a final International Nuclear Event Scale rating level of 2.

Item Number 150479 - A radioactive source manufacturer reported that a technician received a whole body overexposure and an extremity overexposure. The technician was briefly exposed to very high radiation levels while handling a source drawer containing a 135.57 TBq (3,664 Ci) Co-60 source. The incident occurred on 8/20/2015 during a routine source exchange procedure. Technicians were preparing to transfer the source drawer into another shielded container. The involved technician stated that he needed to move the source drawer just enough to expose the bolts on the special handling tool so that it could be removed. However, apparently forgetting that the source drawer was loaded, the technician completely removed the source drawer from the shield, started to bend over and place the drawer onto the floor, then straightened back up and reinserted the drawer back into the shield. The source was exposed for approximately 4 seconds. The technician's electronic dosimeter revealed 56.2 mSv (5.62 rem). Reenactment of the event and conservative calculations revealed a potential whole body exposure of 169 mSv (16.9 rem) and a potential extremity exposure of between 2,370 to 9,500 mGy (237 and 950 rad). The technician was not wearing extremity dosimetry because it was not required for the task. No immediate adverse health effects to the technician were expected, but he was sent to a local hospital for bloodwork. The technician's dosimeter was sent for processing and results revealed an exposure of 2,019 mSv (201.9 rem). However, review of security video of the event from two different angles revealed that the technician's dosimeter, which was hanging on a lanyard, swung away from his body and passed very near the source. The manufacturer believed that the dosimeter received a much higher exposure than the technician. Analysis of blood samples revealed normal results with no indication of excessive radiation exposure. NRC dispatched an inspector to the facility on 8/21/2015. During the approximately 4 second exposure, the technician was exposed to a peak exposure rate of 3,739 R/hour. Dose modeling using microShield software revealed an estimated exposure of 491 mGy (49.1 rad) to the left hand and 72.45 mSv (7.245 rem) to the whole body. The Radiation Emergency Assistance Center/Training Site (REAC/TS) was contacted to discuss and review laboratory results for the technician; they confirmed that bloodwork appears normal and recommended continuing complete blood count testing once daily through 8/28/2015. The technician's finger tips were also examined for symptoms through 8/28/2015 and every other day for three weeks; no reddening or edema was observed. The manufacturer contracted with a university to perform independent exposure assessment of the event. On 9/8/2015, the technician's cytogenetic biodosimetry analysis results revealed a whole body exposure of 504 mGy (50.4 rad). REAC/TS was contacted to discuss the results; they do not consider this to be a "clinically significant dose" and do not recommend further re-testing to validate results because cytogenetic testing may not be valid for a non-uniform exposure. On 10/1/2015, the manufacturer submitted their final conclusion on the technician's dose, which was 56.2 mSv (5.62 rem) to the whole body and 384 mSv (38.4 rem) to the maximally exposed extremity. This event was caused by poor coordination and control of the task. Corrective actions include personnel training and procedure modification. As of 8/21/2015, this incident had a provisional International Nuclear Event Scale rating level of 3.

Events of Interest

Item Number 150147 - On 2/27/2015, a medical center reported that a dosimetry report indicated that a nuclear medicine technologist received a dynamic whole body dose of 11 cSv (rem) for the wear period of 9/1/2014 to 1/7/2015. The technologist only works at the hospital one day per week. The Arizona Radiation Regulatory Agency investigated the event, concluded that the technologist received 11.01 cSv

(rem), and assigned the individual 10 cSv (rem) during 2014 and 1.01 cSv (rem) for 2015. As of 8/21/2015, this incident had a final International Nuclear Event Scale rating level of 2.

2.4.3 Events Recently Added to NMED That Occurred Prior to FY15

No EXP events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events - Immediate or 24-Hour Reporting
None

Events of Interest
None

2.5 Release of Licensed Material or Contamination

2.5.1 Ten-Year Data

Figure 5 displays the annual number and trend of RLM events that occurred during the 10-year period. The trend analysis determined that the data does not represent statistically significant trends in the number of events (indicated by the absence of trend lines). Therefore, variations within the annual values represent random fluctuation around the average of the data.

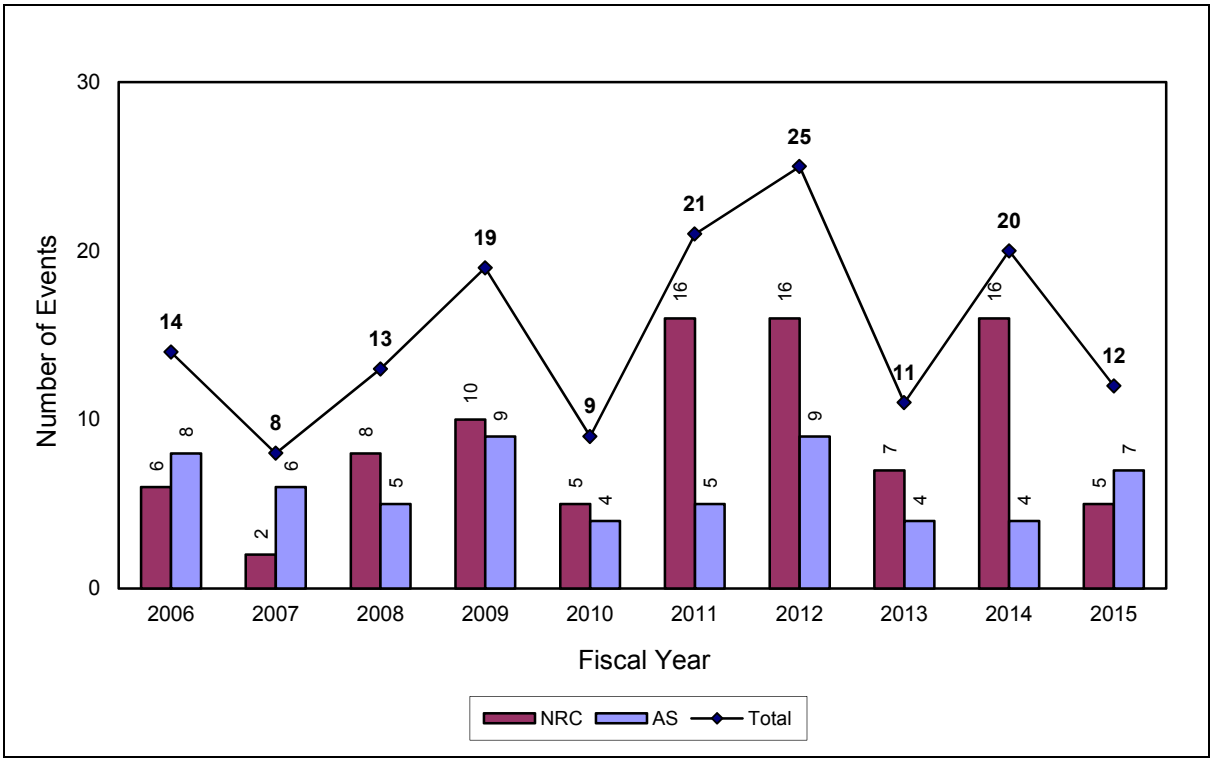

Figure 5. Release of Licensed Material or Contamination Events (152 total)

The significance of individual RLM events may be determined by the CFR reporting requirement applicable to the event. For example, an event that is required to be immediately reported is typically more significant than an event with a 30-day reporting requirement. For this report, events requiring immediate reporting are considered significant. Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

Table 7 displays the number of events based on the different reporting requirement time categories. Note that each event is counted only once. If an event involved exposures that were reportable in more than one category, the event is counted in only the most restrictive category.

Table 7. RLM Events Classified by CFR Reporting Requirement

	Fiscal Year										
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Immediate	0	0	2	1	2	0	2	1	1	0	**9**
24-Hour	12	8	9	13	4	20	21	8	17	12	**124**
30-Day	2	0	2	5	3	1	2	2	2	0	**19**
Total	**14**	**8**	**13**	**19**	**9**	**21**	**25**	**11**	**20**	**12**	**152**

2.5.2 FY15 Data

Twelve RLM events occurred in FY15, none of which were considered significant.

Significant Events - Immediate Reporting
None

Events of Interest
Item Number 140677 - A fire occurred in a university laboratory fume hood on 10/28/2014. A researcher was working with approximately four grams of uranium/technetium metallic alloy, which is pyrophoric. The uranium sample was stored under heavy oil, which had to be removed with hexane prior to use. After the researcher rinsed the uranium sample with hexane, he left the laboratory for about five minutes. When he returned, he found the hood damaged and a small fire still burning. The fire was extinguished. The fire damaged a sharps container of used pipettes with a maximum activity of 5.55 MBq (150 µCi). The inside of the hood was also radioactively contaminated. A breathing zone air sample was being collected in the laboratory at the time of the fire. The air sample head was mounted directly above the hood. That sample was analyzed and revealed negative results. The immediate area outside the hood was surveyed and also revealed negative results. No personnel were contaminated and the laboratory was closed pending investigation. The two high-efficiency particulate air filters for the fume hood, which were undamaged, prevented a release of radioactive material to the environment. The university and the Nevada Division of Radiological Health investigated the incident. Corrective actions included procedure modification and personnel training.

Item Number 150194 - An unplanned chemical reaction occurred in a two-liter polypropylene container at a nuclear fuel manufacturer on 4/4/2015. The container, which held cleaning material, nitric acid, and a small amount of uranium, had been closed, inserted into a plastic bag, sealed, and placed on a rack in a locked storage cage on 4/2/2015. This event was discovered when a supervisor noticed a strong odor coming from the area. Upon investigation, the supervisor and an operator discovered the ruptured and smoldering container on the floor of the storage area and a visible brownish-red haze in the air. The contents of the container had been ejected onto the floor and adjacent areas. The supervisor actuated a nearby fire alarm and the site fire brigade responded and mitigated the smoldering container. The area was roped off and the cleanup process began. NRC initiated a special inspection to assess the circumstances surrounding this event. The area was cleaned up and access restrictions were removed on 4/7/2015. There were no measurable exposures of individuals to radiation or radioactive materials as a result of this event. This event was caused by mixing incompatible materials that had not been adequately rinsed and dried prior to being added to the container. This occurred due to the lack of detailed guidance. Corrective actions included procedure modification and personnel training regarding the adverse chemical reactions that could occur if incompatible materials are mixed. This event was classified as an FCP and RLM event.

Item Number 150213 - A process control instrument manufacturer reported that a 25.68 GBq (694 mCi) Cs-137 source ruptured while a technician was removing it from a fixed gauge. The source had an original activity of 44.4 GBq (1,200 mCi) in 6/1991, with a current activity of 25.68 GBq (694 mCi). The

technician's rate meter alarmed when he attempted to remove the source from the source sleeve. Radiation surveys revealed contamination in the workroom and on the technician, who was immediately decontaminated. Nasal swaps of the technician identified contamination. The technician's dosimetry was sent for immediate processing. Access to the workroom was restricted during decontamination. Initially, radiation surveys identified no radioactive contamination outside of the work room. However, further surveys revealed contamination in other areas of the building as well as in employees' and others' vehicles and residences. The company secured the services of several contractors to assist with this event. Approximately 160 individuals (employees, family members, and others) were screened, four of whom were contaminated. Three of those individuals were directly involved in the incident. Nineteen individuals had items that were contaminated. Over 165 vehicles were surveyed, 29 of which were contaminated. Forty-one residences were surveyed, 15 of which were contaminated. Environmental pathways were sampled, with no regulatory limits exceeded. In addition to the Cs-137 contamination identified, Am-241 contamination was also identified inside the facility, in a vehicle, and in two residences. The company remediated all of the contaminated items, vehicles, and residences and the Texas Department of State Health Services performed independent confirmatory surveys. Whole body in-vivo counting, dosimetry results, and dose assessments for the five individuals identified as having the highest exposure risk indicated no occupational exposures exceeding limits; the highest total effective dose equivalent assessed was 13.45 mSv (1,345 mrem). There is no evidence that any member of the public received an exposure exceeding limits. The most likely cause of the source rupture was the mechanical force used to attempt to remove it from the source sleeve, combined with corrosion of the source capsule from the environment in which the gauge had been used. To prevent recurrence, the company ceased performing source removals. This event was classified as an EQP, LKS, and RLM event.

Item Number 150318 - Material in a waste container set off the radiation monitor alarms at a landfill on 4/13/2015. The radionuclide was identified as Cs-137. The Texas Department of State Health Services performed an onsite investigation and confirmed the material to be dirt/mud contaminated with Cs-137. The contaminated material was isolated. Department staff drove the route traveled by the collection vehicle and performed radiation surveys in an attempt to locate the source. Radiation was identified in a drainage ditch along the side of the road near the intersection of Sunbury and Bacher Streets in Houston, Texas. Initial surface readings obtained in the ditch ranged from 430 μR/hour to 16 mR/hour. Surveys also indicated additional activity as far as 70 feet from the hottest spot. The ditch was closed by the city. A contractor was hired and started remediation of the area on 5/21/2015. During remediation, radiation surveys revealed up to 1 R/hour, at about three feet from the original surface of the ditch. Soil was removed to a maximum depth of 14 feet. The contractor used a low pressure water blaster to excavate the area. The remediated water was collected in barrels. The owner of the Cs-137 could not be determined. This event was classified as an EQP, LAS, and RLM event.

Item Number 150319 - An oil and gas services company reported that a Cs-137/Ba-137m generator containing Cs-137 with an original activity of 1,811.52 MBq (48.96 mCi) was leaking. Routine radiation surveys of the source storage area performed on 5/18/2015 revealed removable Cs-137 contamination. Further surveys identified that the generator was leaking. The Cs-137 is in the form of small resin spheres (about the size of poppy seeds), with Cs-137 coating their surface. Access to the area in which the generator resides was restricted (for greater than 24 hours). Investigation revealed that small amounts of Cs-137 had been tracked into the office area and some of their work vehicles. The leaking generator was placed inside a Type A drum. Investigation revealed that the generator's tubing and connector were replaced in December 2014 after the connector broke. On 5/8/2015, an authorized employee removed the generator from its container, examined it on an empty drum for an upcoming job, and then placed it back into its container. On 5/12/2015, that empty drum was moved to an enclosed work trailer. Shortly thereafter, radiation surveys of the office building revealed 61 spots of radioactive contamination. Those spots were remediated. Nine residences were surveyed and five had small amounts of contamination (less than regulatory limits), but one had more distributed contamination (exceeding regulatory limits). All

contaminated residences were remediated. Five work trucks, trailers, and equipment were surveyed and all five were contaminated. Three revealed above background results but below regulatory limits and two revealed more distributed contamination (exceeding regulatory limits). All were remediated. Sixteen employees were sent for whole body counting and no radiation uptakes were identified. Dosimetry reports also revealed no external radiation exposures to personnel. The company began remediation of the source storage area. On 6/30/2015, trash from the facility set off the radiation monitor alarms at a Houston, Texas, landfill. Two bags were identified as containing Cs-137 contamination. The company is investigating how the material got into their regular trash. Continued investigation revealed that initial leakage began in October 2014 (see NMED Item 150574). Initial corrective actions included adding radiation contamination monitoring stations, increasing the frequency of contamination surveys, and disposing of some equipment. The company will also review their radiation management procedures and review the competency of their radiation workers. The Texas Department of State Health Services is investigating the incident. This event was classified as an EQP and RLM event.

2.5.3 Events Recently Added to NMED That Occurred Prior to FY15

One RLM event was recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. This event was not considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events - Immediate Reporting
None

Events of Interest
None

2.6 Leaking Sealed Sources

2.6.1 Ten-Year Data

Figure 6 displays the annual number and trend of LKS events that occurred during the 10-year period. The trend analysis determined that the data do not represent statistically significant trends (indicated by the absence of trend lines). Therefore, variations within the annual values represent random fluctuation around the average of the data.

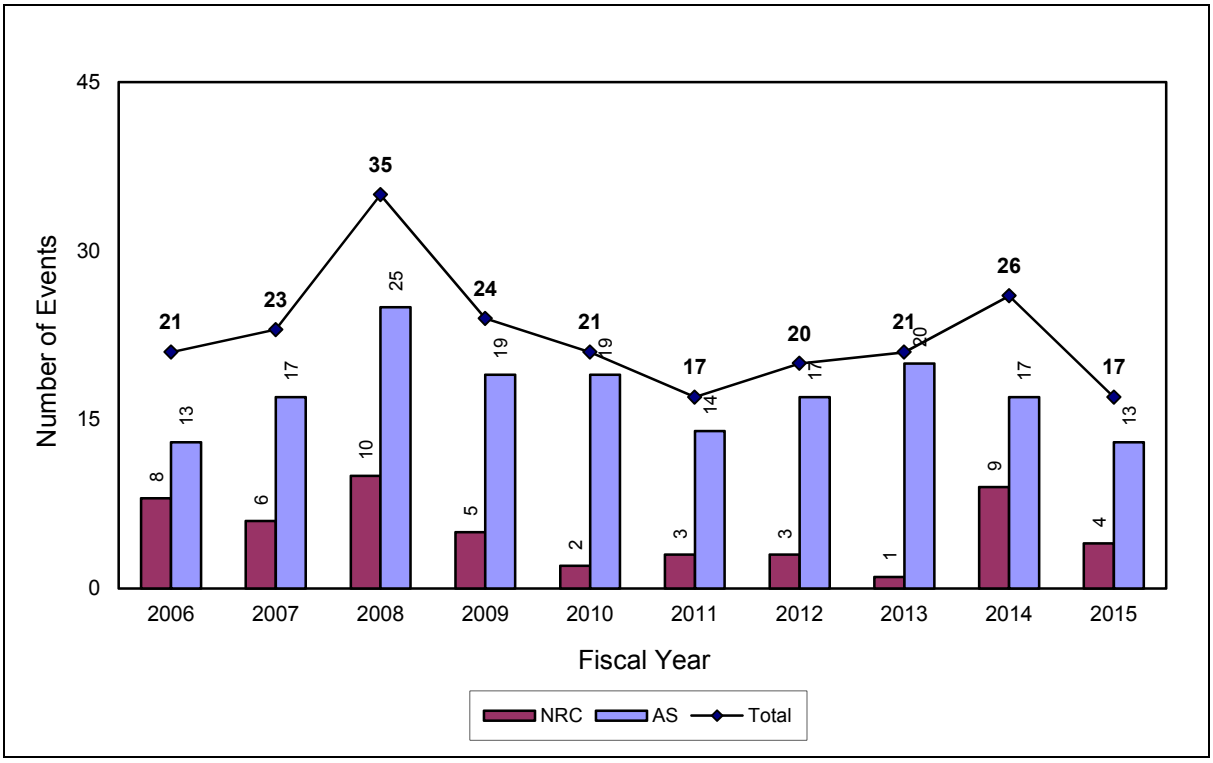

Figure 6. Leaking Sealed Source Events (225 total)

It is not possible to discern the significance of LKS events strictly from the CFR reporting requirements (as in Sections 2.4, 2.5, and 2.9). There are essentially no immediate or 24-hour reporting requirements for leaking sources. The exception is 39.77(a), which is an immediate report to the NRC Regional office of a ruptured well logging source. Therefore, event significance will be determined on an event-by-event basis based on the severity of the event (e.g., significant exposure to workers, members of the public, and/or the environment). Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

2.6.2 FY15 Data

Seventeen LKS events occurred in FY15, none of which were considered significant.

Significant Events
None

Events of Interest
Item Number 150213 - A process control instrument manufacturer reported that a 25.68 GBq (694 mCi) Cs-137 source ruptured while a technician was removing it from a fixed gauge. The source had an original activity of 44.4 GBq (1,200 mCi) in 6/1991, with a current activity of 25.68 GBq (694 mCi). The technician's rate meter alarmed when he attempted to remove the source from the source sleeve. Radiation surveys revealed contamination in the workroom and on the technician, who was immediately

decontaminated. Nasal swaps of the technician identified contamination. The technician's dosimetry was sent for immediate processing. Access to the workroom was restricted during decontamination. Initially, radiation surveys identified no radioactive contamination outside of the work room. However, further surveys revealed contamination in other areas of the building as well as in employees' and others' vehicles and residences. The company secured the services of several contractors to assist with this event. Approximately 160 individuals (employees, family members, and others) were screened, four of whom were contaminated. Three of those individuals were directly involved in the incident. Nineteen individuals had items that were contaminated. Over 165 vehicles were surveyed, 29 of which were contaminated. Forty-one residences were surveyed, 15 of which were contaminated. Environmental pathways were sampled, with no regulatory limits exceeded. In addition to the Cs-137 contamination identified, Am-241 contamination was also identified inside the facility, in a vehicle, and in two residences. The company remediated all of the contaminated items, vehicles, and residences and the Texas Department of State Health Services performed independent confirmatory surveys. Whole body in-vivo counting, dosimetry results, and dose assessments for the five individuals identified as having the highest exposure risk indicated no occupational exposures exceeding limits; the highest total effective dose equivalent assessed was 13.45 mSv (1,345 mrem). There is no evidence that any member of the public received an exposure exceeding limits. The most likely cause of the source rupture was the mechanical force used to attempt to remove it from the source sleeve, combined with corrosion of the source capsule from the environment in which the gauge had been used. To prevent recurrence, the company ceased performing source removals. This event was classified as an EQP, LKS, and RLM event.

Item Number 150237 - A medical center reported that a 49.21 MBq (1.33 mCi) I-125 brachytherapy seed was leaking. This event was discovered after a medical physicist and resident prepared eye plaques for treatment of ocular melanoma. A review of the eye plaques on 4/9/2015 revealed that the methyl methacrylate used to adhere the seeds to the eye plaques had not cured properly. The eye plaques were soaked overnight in acetone in order to remove the seeds. On the morning of 4/10/2015, the seeds were transferred to a lead container and the acetone was surveyed with a Geiger-Mueller probe. Significant counts above background were identified. Additional surveys identified contamination on the hot lab desk. The leaking source was isolated and taken out of service. Thyroid bioassays of the resident and the medical physicist revealed that the resident had no detectable uptake. However, the medical physicist had an uptake of 652.7 Bq (17.64 nCi), with an estimated committed dose equivalent of 220 μSv (22 mrem) to the thyroid and an estimated committed effective dose equivalent of 9 μSv (0.9 mrem). The medical physicist requested that his daughter be given a bioassay, which revealed an uptake below minimal detectable activity. The root cause of the leaking source was most likely the use of a scalpel by the medical physicist while inspecting the eye plaques; a visual inspection of the seed showed two small holes. The spread of contamination was likely caused by the use of a Geiger-Mueller probe that was inadequate to detect the contamination. Corrective actions included limiting the use of tools to those without sharp edges, purchasing a Sodium Iodide probe, improved survey methods, and contacting the seed manufacturer. This event was classified as an EQP and LKS event.

2.6.3 Events Recently Added to NMED That Occurred Prior to FY15

Three LKS events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. None of these events were considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events
None

Events of Interest
None

2.7 Equipment

2.7.1 Ten-Year Data

Figure 7 displays the annual number and trend of EQP events that occurred during the 10-year period. The trend analysis determined that the NRC-regulated events represent a statistically significant decreasing trend (indicated by the trend lines). However, the Agreement-State regulated and Total events do not represent statistically significant trends in the number of events (indicated by the absence of trend lines). Therefore, variations within the Total and Agreement State values represent random fluctuation around the average of the data.

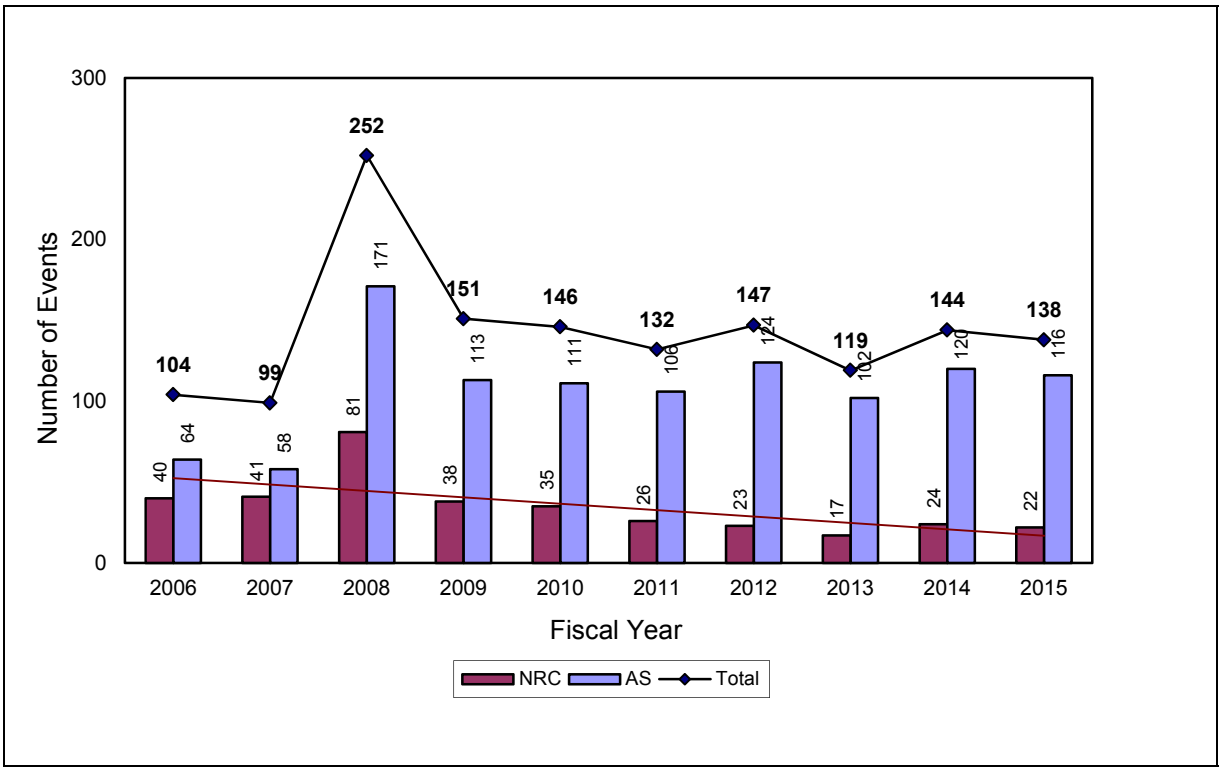

Figure 7. Equipment Events (1,432 total)

The FY08 and 09 data include 131 and 20 EQP events, respectively, which resulted from Wal-Mart's one-time review of their tritium exit sign inventory.

It is not possible to discern the significance of EQP events strictly from the CFR reporting requirements (as in Sections 2.4, 2.5, and 2.9) because essentially all of the CFRs associated with EQP events require reporting within 24-hours. Therefore, event significance will be determined on an event-by-event basis based on the severity of the event (e.g., significant exposure to workers, members of the public, and/or the environment). Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

2.7.2 FY15 Data

One hundred thirty-eight EQP events occurred in FY15, four of which were considered significant.

Significant Events

Item Number 140755 - A nuclear fuel manufacturer reported that a check valve [an Item Relied On For Safety (IROFS)] on a steam supply subsystem failed an annual preventive maintenance test on 10/20/2014. The check valve did not adequately seal, which caused it to fail to prevent backflow into an

unfavorable geometry steam boiler. The boiler was down at the time and the system remained down until compensatory actions were in place such that the check valve was not needed to meet the performance criteria. The check valve had likely been in that condition for more than eight hours, leaving only one additional IROFS in place to prevent reverse flow of uranium-bearing solution into the steam separator. The safety impact of this incident is low. An apparent cause analysis was initiated. Interim corrective actions included isolating the heat exchanger from the system using blind flanges and by locking the inlet and outlet valves closed. The manufacturer plans to replace the check valve with a different and more reliable passive/active engineered IROFS by 4/30/2015. This event was classified as an EQP and FCP event.

Item Number 150049 - A radiographer was overexposed at a refinery in Baton Rouge, Louisiana, on 1/16/2015. The incident involved a 1,410 GBq (38.1 Ci) I-192 source. Following operations, the radiographer attempted to disconnect the guide tube from the exposure device, but it would not disconnect. He determined that the source was not locked in the device and that the locking mechanism indicator was red. A radiographer instructor manipulated the crank assembly a quarter of a turn and fully retracted the source. The exposed radiographer's pocket dosimeter was off scale, but he claimed that his alarming rate meter did not alarm. It was determined that the rate meter alarmed, but it was weak. The radiography company confirmed that the radiographer's whole body exposure was 64 mSv (6.4 rem) and his extremity exposure was 2,060 mGy (206 rad) to his hands. The radiographer was taken to a medical facility for examination. The instructor was retrained in radiation safety practices, lost his instructor status, and has been suspended from radiation work. The exposed radiographer is no longer employed at the company and will not respond to correspondence. The Louisiana Department of Environmental Quality investigated the event. The cause appears to be operator error. As of 1/23/2015, this incident had a final International Nuclear Event Scale rating level of 2. This event was classified as an EQP and EXP event.

Item Number 150140 - A medical center reported eight medical events involving a gamma knife unit that contained 244.2 TBq (6,600 Ci) of Co-60. The patients were being treated for acoustic neuromas and metastatic tumors in the brain. All eight patients received their prescribed doses, ranging from 700 to 2,490 cGy (rad), to the wrong location due to misalignment of the patient positioning system. This misalignment occurred during maintenance of the unit between 12/13/2014 and 1/1/2015 by the manufacturer, with resulted in the patient positioning system being off-target by 1.87 mm. The eight patient treatments were performed between 1/7 and 2/12/2015. All of the patients and referring physicians were notified. The effects to the patients are still being determined. The cause of the misalignment of the patient positioning system was the failure to use the correct service procedures during maintenance. Corrective actions include the development of a new set of tests to verify patient positioning. This event was classified as an EQP and MED event.

Item Number 150156 - A radiography services company reported that personnel overexposures occurred on 3/17/2015. The incident occurred at a power plant during radiography operations using an exposure device that contained a 2.812 TBq (76 Ci) Ir-192 source. A crew of one radiographer and three assistants were completing two exposures lasting 35 seconds, with a set-up time of approximately 15 to 18 minutes. Following the exposures, the radiographer's pocket dosimeter was off-scale (>200 mR), the first assistant's was reading 50 mR, the second assistant's was off-scale, and the third assistant was not wearing any dosimetry. The radiographer and first assistant acknowledged that their alarming rate meters were functioning properly. The second and third assistants were not wearing alarming rate meters. The crew stopped work, notified their RSO (at 2130), and met with the RSO the following morning to discuss the incident. Only the radiographer and first assistant were wearing dosimetry badges. The dosimetry badges were sent for emergency processing. The results revealed exposures of 11.2 and 5 cSv (rem) to the radiographer and first assistant, respectively. The company's preliminary estimate determined that the third assistant (not wearing any dosimetry) may have received a whole body exposure of up to 45 cSv (rem). They determined that the radiation survey meter had an electrical short and did not function

properly. The radiography exposure device was checked and functioned properly. The Alabama Department of Public Health visited the power plant, met with plant representatives, and reviewed the area where the incident took place. They also interviewed the company RSO and all involved personnel. The Department determined that the source was outside of the exposure device but not in the guide tube. The four radiography personnel involved were seen by an occupational physician and submitted blood samples that were sent to the Radiation Emergency Assistance Center/Training Site (REAC/TS) for cytogenic biodosimetry. REAC/TS determined that all four individuals had exposures of less than the minimum threshold of 20 cSv (rem). The primary causes of the incident appear to be failure to use an operable radiation survey meter and failure to follow procedures. Corrective actions included terminating employment of personnel and providing additional training to personnel. Personnel exposures assigned to the four individuals were: 11.232 cSv (rem) to the radiographer, 5 cSv (rem) to the first and second assistants, and 20 cSv (rem) to the third assistant. As of 9/23/2015, this incident had a final International Nuclear Event Scale rating level of 2. This event was classified as an EQP and EXP event.

Events of Interest

Item Number 150015 - A 2,923 GBq (79 Ci) Co-60 source disconnected from a radiography exposure device during operations at a licensed site in Houston, Texas, on 12/23/2014. After completing an exposure, the radiographers cranked the source back into the device. However, as they approached the end of the source guide tube, survey meters and alarming rate meters indicated that the source was still in the guide tube. The radiography team adjusted boundaries, secured the area, and contacted their supervisor. The RSO and two approved source recovery personnel responded to the site. They determined that the source pigtail had broken several inches from the source. The source was retrieved from the guide tube and placed back into the exposure device. A radiation survey confirmed that the source was in the shielded position. The radiography exposure device and all involved equipment was sent to the manufacturer for evaluation. The evaluation revealed that the cable in the source assembly had been previously repaired/spliced in January 2012 about 3.75 inches from Co-60 source, due to severe fraying. The break occurred immediately behind that splice. The crimped sleeve from the splice caused the adjacent section of the pigtail to flex more than is typical. That extreme flexing resulted in failure. The manufacturer also identified a section of the exposure device's S-tube that was slightly crushed, potentially contributing to the pigtail damage. Inspection revealed significant wear on the pigtail connector body and piston from extensive use. The manufacturer stated that there was only one other spliced Co-60 source pigtail in service and that it would be inspected. The manufacturer is investigating different designs of repairing/splicing source pigtails to prevent recurrence. The Texas Department of State Health Services investigated the incident.

Item Number 150041 - A nuclear fuel manufacturer reported an unplanned fire in a research laboratory. On 1/21/2015, testing of a proposed method for the recovery of uranium from used polypropylene cartridge filters was being conducted. The test involved placing a sample filter into a furnace located inside a ventilation hood. The furnace door was closed once the heating process was initiated. When the furnace reached its target temperature, flames were observed at the top of the furnace door. The flames were fully contained within the confines of the ventilation hood. After observing the flames grow progressively larger, the technician de-energized the furnace and the fire self-extinguished. The flames lasted for approximately 5 to 10 minutes. The ventilation hood glass developed spider cracks and delamination but was fully contained in the sash. The amount of material introduced into the furnace appears to have exceeded the capacity of the furnace. Immediate corrective actions included shutdown of the affected and similar equipment pending inspection and performance of any repairs. A formal assessment process was implemented prior to authorizing the restart of the equipment. Additional testing of the uranium recovery method was suspended pending further evaluation and development of enhanced test procedures. This event was classified as an EQP and FCP event.

Item Number 150048 - On 12/8/2014, a cement manufacturing company reported higher than normal radiation levels during a routine inspection of a fixed gauge that contained a 44.4 GBq (1.2 Ci) Cs-137

source. During the previous semi-annual inspection, the radiation level two feet from the gauge was 0.06 mR/hr. During the inspection on 11/23/2014, levels of 1.2 to 1.4 mR/hr were measured. A radiation safety consultant confirmed the measurements and discovered that the lead shield was no longer intact. It appeared that the lead had slowly melted over time and lost its structural cohesion. No personnel exposure issues were expected. The manufacturer was contacted and a service call was scheduled for January 2015.

Item Number 150100 - A medical center reported that their gamma stereotactic radiosurgery unit experienced a collision error approximately 35 seconds prior to the completion of a 47-minute treatment performed on 2/13/2015. The unit contained Co-60 sources with a combined activity of 222 TBq (6,000 Ci). The medical center was not able to clear the error code and the treatment was aborted. Clinic staff had to manually retract the patient bed from the unit and remove the patient from the room. The patient received 97% of the prescribed dose. Once the error message was received, the sources retracted into their home positions, but the shielding doors remained open. The wall radiation monitor revealed 5 mR/hour. The authorized medical physicist reentered the room and manually closed the shielding doors. The error code could not be cleared and the unit received a forced shutdown. A manufacturer representative responded to the site on 2/16/2015. They determined that the collision error resulted from the collection of moisture (patient tears) inside the collimator cap. The medical center was able to restart the unit on 2/16/2015 after the moisture had evaporated. The manufacturer provided training to personnel on how to remove and dry the collimator cap should the incident happen again.

Item Number 150206 - A patient prescribed a fractional dose of 340 cGy (rad) only received 60 cGy (rad) on 4/13/2015. The patient was receiving brachytherapy treatment to the right breast using an 11-channel strut adjusted volume implant applicator, a high dose rate (HDR) unit, and a 251.16 GBq (6.788 Ci) Ir-192 source. The patient was treated with two channels, but a friction event occurred while sending out the check cable in the third channel and the HDR unit was unable to fully retract the check cable. The medical center stopped the treatment and manually retracted the check cable into the HDR unit. After performing additional tests of the safety check, the check cable became jammed within the HDR unit. The patient and prescribing physician were informed of the event on 4/13/2015. The medical center contacted the vendor and ceased treatments pending repair. The vendor replaced the check cable on 4/14/2015 and returned the HDR unit to service. An inspection of the faulty check cable revealed a fray approximately 0.5 cm behind the welded junction. The interrupted treatment was resumed on 4/14/2015. During NRC's reactive inspection, it was revealed that a prior event involving a damaged check cable was experienced during a routine source exchange on 11/7/2014. During a subsequent source exchange on 5/28/2015, another damaged check cable was identified. The damage on all three check cables was in the same location. Investigation into the cause of the damaged check cables continues. Pending final resolution, the check cable will be examined biweekly for any indications of damage. This event was classified as an EQP and MED event.

Item Number 150213 - A process control instrument manufacturer reported that a 25.68 GBq (694 mCi) Cs-137 source ruptured while a technician was removing it from a fixed gauge. The source had an original activity of 44.4 GBq (1,200 mCi) in 6/1991, with a current activity of 25.68 GBq (694 mCi). The technician's rate meter alarmed when he attempted to remove the source from the source sleeve. Radiation surveys revealed contamination in the workroom and on the technician, who was immediately decontaminated. Nasal swaps of the technician identified contamination. The technician's dosimetry was sent for immediate processing. Access to the workroom was restricted during decontamination. Initially, radiation surveys identified no radioactive contamination outside of the work room. However, further surveys revealed contamination in other areas of the building as well as in employees' and others' vehicles and residences. The company secured the services of several contractors to assist with this event. Approximately 160 individuals (employees, family members, and others) were screened, four of whom were contaminated. Three of those individuals were directly involved in the incident. Nineteen individuals had items that were contaminated. Over 165 vehicles were surveyed, 29 of which were

contaminated. Forty-one residences were surveyed, 15 of which were contaminated. Environmental pathways were sampled, with no regulatory limits exceeded. In addition to the Cs-137 contamination identified, Am-241 contamination was also identified inside the facility, in a vehicle, and in two residences. The company remediated all of the contaminated items, vehicles, and residences and the Texas Department of State Health Services performed independent confirmatory surveys. Whole body in-vivo counting, dosimetry results, and dose assessments for the five individuals identified as having the highest exposure risk indicated no occupational exposures exceeding limits; the highest total effective dose equivalent assessed was 13.45 mSv (1,345 mrem). There is no evidence that any member of the public received an exposure exceeding limits. The most likely cause of the source rupture was the mechanical force used to attempt to remove it from the source sleeve, combined with corrosion of the source capsule from the environment in which the gauge had been used. To prevent recurrence, the company ceased performing source removals. This event was classified as an EQP, LKS, and RLM event.

Item Number 150237 - A medical center reported that a 49.21 MBq (1.33 mCi) I-125 brachytherapy seed was leaking. This event was discovered after a medical physicist and resident prepared eye plaques for treatment of ocular melanoma. A review of the eye plaques on 4/9/2015 revealed that the methyl methacrylate used to adhere the seeds to the eye plaques had not cured properly. The eye plaques were soaked overnight in acetone in order to remove the seeds. On the morning of 4/10/2015, the seeds were transferred to a lead container and the acetone was surveyed with a Geiger-Mueller probe. Significant counts above background were identified. Additional surveys identified contamination on the hot lab desk. The leaking source was isolated and taken out of service. Thyroid bioassays of the resident and the medical physicist revealed that the resident had no detectable uptake. However, the medical physicist had an uptake of 652.7 Bq (17.64 nCi), with an estimated committed dose equivalent of 220 μSv (22 mrem) to the thyroid and an estimated committed effective dose equivalent of 9 μSv (0.9 mrem). The medical physicist requested that his daughter be given a bioassay, which revealed an uptake below minimal detectable activity. The root cause of the leaking source was most likely the use of a scalpel by the medical physicist while inspecting the eye plaques; a visual inspection of the seed showed two small holes. The spread of contamination was likely caused by the use of a Geiger-Mueller probe that was inadequate to detect the contamination. Corrective actions included limiting the use of tools to those without sharp edges, purchasing a Sodium Iodide probe, improved survey methods, and contacting the seed manufacturer. This event was classified as an EQP and LKS event.

Item Number 150308 - A moisture/density gauge was damaged by heavy machinery at a construction site in Barrington, Illinois, on 5/21/2015. The gauge contained an Am-Be source with an activity of 1.48 GBq (40 mCi) and a Cs-137 source with an activity of 0.3 GBq (8 mCi). The gauge operator had been called away from the gauge, which was struck during his absence. The gauge operator gathered up the pieces of the gauge and placed them into its transportation container. The gauge operator was in the process of returning the broken gauge to the company storage facility in Chicago, Illinois, when the RSO was notified. Pictures sent to the RSO revealed that the Cs-137 source rod was significantly bent approximately four inches from its end and the source was not in its shielded position. The operator secured the gauge in a remote location of the storage facility upon return. The next morning, Illinois Emergency Management Agency inspectors arrived at the facility to conduct radiation surveys and leak tests. Leak tests revealed negative results. Surveys revealed up to 60 mR/hour at the surface of the transportation case. The gauge pieces were reconfigured and secured at the site. Exposure rates were lowered to 16 mR/hour near the surface of the case and less than 1 mR/hour at one foot. The manufacturer was contacted, provided a shipping container and shielding, and the gauge was returned to them. Initial corrective actions included reprimanding involved personnel and providing them with additional training.

Item Number 150318 - Material in a waste container set off the radiation monitor alarms at a landfill on 4/13/2015. The radionuclide was identified as Cs-137. The Texas Department of State Health Services

performed an onsite investigation and confirmed the material to be dirt/mud contaminated with Cs-137. The contaminated material was isolated. Department staff drove the route traveled by the collection vehicle and performed radiation surveys in an attempt to locate the source. Radiation was identified in a drainage ditch along the side of the road near the intersection of Sunbury and Bacher Streets in Houston, Texas. Initial surface readings obtained in the ditch ranged from 430 μR/hour to 16 mR/hour. Surveys also indicated additional activity as far as 70 feet from the hottest spot. The ditch was closed by the city. A contractor was hired and started remediation of the area on 5/21/2015. During remediation, radiation surveys revealed up to 1 R/hour, at about three feet from the original surface of the ditch. Soil was removed to a maximum depth of 14 feet. The contractor used a low pressure water blaster to excavate the area. The remediated water was collected in barrels. The owner of the Cs-137 could not be determined. This event was classified as an EQP, LAS, and RLM event.

Item Number 150319 - An oil and gas services company reported that a Cs-137/Ba-137m generator containing Cs-137 with an original activity of 1,811.52 MBq (48.96 mCi) was leaking. Routine radiation surveys of the source storage area performed on 5/18/2015 revealed removable Cs-137 contamination. Further surveys identified that the generator was leaking. The Cs-137 is in the form of small resin spheres (about the size of poppy seeds), with Cs-137 coating their surface. Access to the area in which the generator resides was restricted (for greater than 24 hours). Investigation revealed that small amounts of Cs-137 had been tracked into the office area and some of their work vehicles. The leaking generator was placed inside a Type A drum. Investigation revealed that the generator's tubing and connector were replaced in December 2014 after the connector broke. On 5/8/2015, an authorized employee removed the generator from its container, examined it on an empty drum for an upcoming job, and then placed it back into its container. On 5/12/2015, that empty drum was moved to an enclosed work trailer. Shortly thereafter, radiation surveys of the office building revealed 61 spots of radioactive contamination. Those spots were remediated. Nine residences were surveyed and five had small amounts of contamination (less than regulatory limits), but one had more distributed contamination (exceeding regulatory limits). All contaminated residences were remediated. Five work trucks, trailers, and equipment were surveyed and all five were contaminated. Three revealed above background results but below regulatory limits and two revealed more distributed contamination (exceeding regulatory limits). All were remediated. Sixteen employees were sent for whole body counting and no radiation uptakes were identified. Dosimetry reports also revealed no external radiation exposures to personnel. The company began remediation of the source storage area. On 6/30/2015, trash from the facility set off the radiation monitor alarms at a Houston, Texas, landfill. Two bags were identified as containing Cs-137 contamination. The company is investigating how the material got into their regular trash. Continued investigation revealed that initial leakage began in October 2014 (see NMED Item 150574). Initial corrective actions included adding radiation contamination monitoring stations, increasing the frequency of contamination surveys, and disposing of some equipment. The company will also review their radiation management procedures and review the competency of their radiation workers. The Texas Department of State Health Services is investigating the incident. This event was classified as an EQP and RLM event.

Item Number 150328 - A steel manufacturer reported on 6/4/2015 that the shutter on a fixed nuclear gauge was stuck open on a furnace at their hot rolling facility. The gauge contained a 37 GBq (1 Ci) Cs-137 source. The manufacturer also identified possible shielding compromise and leakage of lead. The RSO was contacted and responded to the site. Radiation surveys revealed no differences in results compared to prior radiation surveys performed on the operational gauge. Wipe tests also revealed negative results. Melted metallic material was found adjacent to the gauge housing and was believed to be lead from the shielding. The RSO believed the shielding may have been overheated and may be blocking the shutter open. The gauge was left in operation until it was removed from its mounted location on 6/9/2015. The gauge was then placed into a shielded container for onsite storage until retrieved by the gauge manufacturer for repair. It was determined that the lead shutter had melted due to a missing ceramic fiber cover, which kept the gauge from overheating. It is believed the ceramic fiber

cover was moved out of position due to abnormally high positive pressure in the furnace. All remaining nuclear gauges were examined to ensure their ceramic fiber covers were intact.

Item Number 150413 - A moisture/density gauge was struck by a car on 7/16/2015 in Wichita, Kansas. The gauge contained a 1.48 GBq (40 mCi) Am-Be source and a 0.3 GBq (8 mCi) Cs-137 source. The gauge was in use at the time of the incident and was completely destroyed. The source plate containing the neutron source could be seen, but the Cs-137 source rod was stuck in the car that hit the gauge. The sources were placed into a five-gallon bucket of dirt for shielding and transported to the company's storage facility. The bucket was placed into a secure area and the manufacturer was contacted for return shipment instructions. The Kansas Department of Health and Environment confirmed that the sources were secured on 7/16/2015. Leak tests revealed negative results. The gauge was returned to the manufacturer on 9/9/2015.

Item Number 150509 - The Utah Department of Transportation reported that a portable density gauge was run over by three vehicles at a construction site on eastbound I-215 at Redwood Road on 9/4/2015. The gauge contained a 0.3 GBq (8 mCi) Cs-137 source. The incident occurred while the gauge operator was performing a measurement. The gauge was destroyed and the source shielding was demolished. The source remained intact and no leakage was identified. The manufacturer is sending an appropriate shipping container to return the source in. The Department is authorized to remove the source rod from the gauge. They will remove the source and place it into a shield for transport.

2.7.3 Events Recently Added to NMED That Occurred Prior to FY15

Fourteen EQP events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. None of these events were considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events
None

Events of Interest
Item Number 150228 - A badly damaged moisture/density gauge was found in a load of scrap metal. On 9/4/2014, the California Highway Patrol notified the California Radiologic Health Branch (CRHB) that a truck had triggered a radiation alarm. The scrap metal originated at a recycling facility in Phoenix, Arizona. The driver was instructed to take the material to its home destination in Carson, California. A CRHB inspector arrived at the facility that same day. Using a Bicron MicroRem meter, net exposure rates were 30 µSv/hr (3,000 µrem/hr) at the surface of the scrap metal container, with 4.5 µSv/hr (450 µrem/hour) at one foot, and 1.7.5 µSv/hr (175 µrem/hr) at three feet (background was 0.04 µSv/hr or 4 µrem/hr). Using a Canberra Inspector 1000 multi-channel analyzer, the radionuclide was identified as Cs-137. The material was transferred to a scrap metal facility in Los Angeles, California, where it was dumped and sorted. A radioactive waste services company was contracted to identify the radioactive material. On 9/11/2014, they reported that the radioactive material consisted of a damaged moisture/density gauge (Troxler model 3450, serial #00533) that contained a 1.48 GBq (40 mCi) Am-Be source and a 0.3 GBq (8 mCi) Cs-137 source. CRHB placed the gauge in their radioactive storage location in Baldwin Park, California. CRHB was able to identify the original owner of the gauge, who had reported the gauge as stolen on 6/14/2014 (see NMED Item Number 140324). The damaged gauge was removed from the California storage facility and transferred to a licensed gauge service center on 3/20/2015. Leak testing revealed that neither radioactive source was leaking or damaged. The gauge manufacturer approved return of the gauge to them for proper disposal. This event was classified as an EQP and LAS event.

Item Number 150336 - A moisture/density gauge was run over by a front-end loader and damaged at a construction site in Parker, Colorado, on 6/6/2014. The gauge contained a 1.48 GBq (40 mCi) Am-Be

source and a 0.3 GBq (8 mCi) Cs-137 source. The technician had left the gauge in the soil compaction area and walked to his truck approximately 50 feet away. The loader ran over the gauge and broke it apart. The Cs-137 source rod was not in its shield after the collision. The Cs-137 source was placed into a lead pig. The gauge pieces were collected, placed into the gauge case, and will be taken to a service provider. Radiation surveys revealed 0.3 mR/hour at one meter from the case. Leak tests revealed negative results for both sources. Corrective actions included providing additional training to personnel.

Item Number 150463 - A paper company reported that the lead shielding around the source holders of two fixed gauges had separated from the original fabrication. The two gauges each contained a 185 GBq (5 Ci) Cs-137 source and were damaged sometime in May 2014. The Arkansas Department of Health became aware that the gauges had been repaired on 6/5/2014 and the field service report indicated the shutters were not closed during those repairs. It was determined that no public exposures above regulatory limits occurred.

2.8 Transportation

2.8.1 Ten-Year Data

Figure 8 displays the annual number and trend of TRS events that occurred during the 10-year period. The trend analysis determined that the data does not represent statistically significant trends in the number of events (indicated by the absence of trend lines). Therefore, variations within those annual values represent random fluctuation around the average of the data.

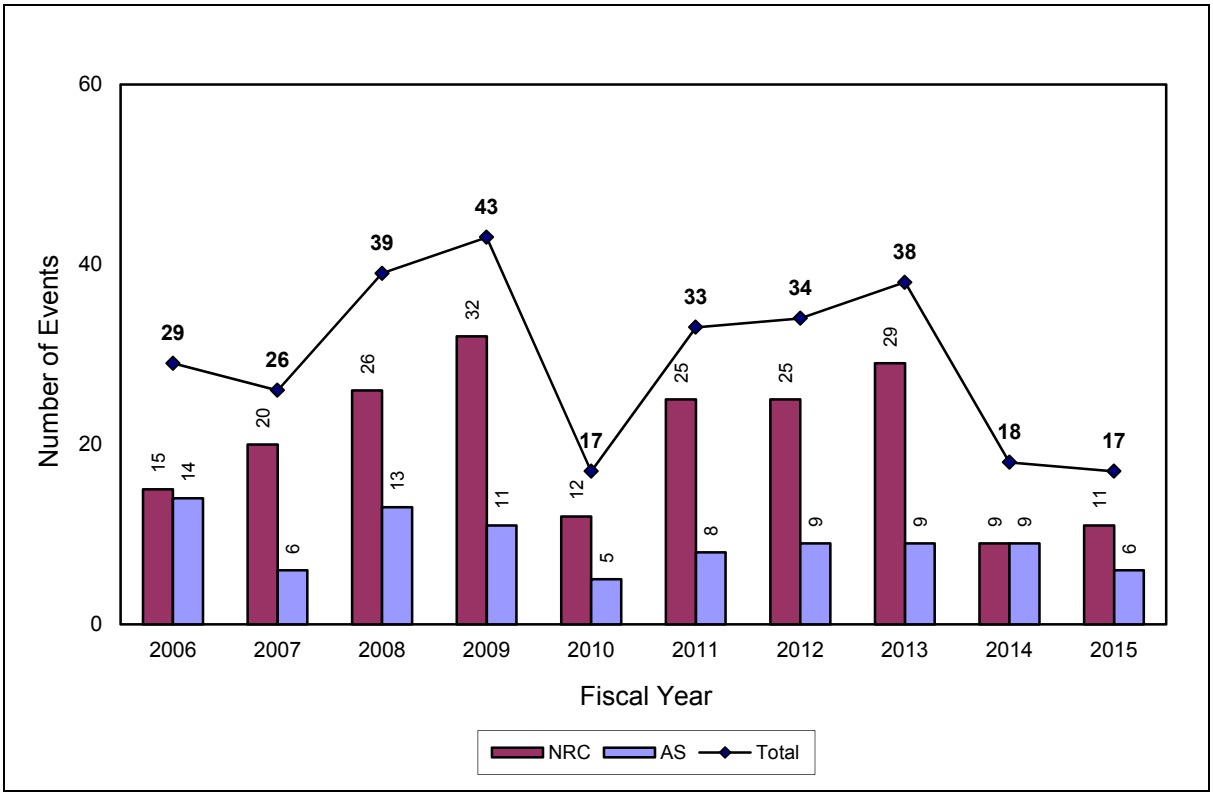

Figure 8. Transportation Events (294 total)

It is not possible to discern the significance of TRS events strictly from the CFR reporting requirements (as in Sections 2.4, 2.5, and 2.9). Therefore, event significance will be determined on an event-by-event basis based on the severity of the event (e.g., significant exposure to workers, members of the public, and/or the environment). Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

2.8.2 FY15 Data

Seventeen TRS events occurred in FY15, none of which were considered significant.

Significant Events
None

Events of Interest
Item Number 150321 - A nuclear energy equipment maintenance company reported receiving a package containing filters that exceeded the contact exposure rate limit of 200 mR/hour. Confirmatory instruments indicated an exposure rate of 307 mR/hour on contact with the bottom of the package, 75 mR/hour at one foot, and 16 mR/hour at three feet. No removable contamination was identified. The package contained a total of 22.27 GBq (601.80 mCi) of Co-60. The package was shipped from a related facility in Belgium. They maintain that the package met all transportation requirements prior to

departure. The Pennsylvania Department of Environmental Protection performed a reactive inspection. It was determined that the shipper used half-round lead blankets to shield the underside of the inner shipping container. Those half-round blankets allowed gaps due to equipment movement during transport. That created small hot spots on the bottom of the package. The shipper took corrective actions to prevent recurrence, including changes to the type of shielding used and training to personnel preparing radioactive shipments.

Item Number 150472 - A radiopharmaceutical company received a shipment of F-18 from the manufacturer with a maximum surface radiation reading of 210 mR/hour on 8/13/2015. The area along the gap between the lid and the body of the shipping package revealed the highest dose rates of between 180 and 230 mR/hour. The company opened the package and discovered that the lid of the secondary shield was not present. They removed the pig containing the F-18 and observed that the screw top was not properly secured; the thread of the lid and body did not align. Therefore, there was a gap in the shielding. There was no damage to the vial containing the F-18. The New Jersey Department of Environmental Protection will follow up with the F-18 manufacturer to determine corrective actions.

2.8.3 Events Recently Added to NMED That Occurred Prior to FY15

Six TRS events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. None of these events were considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events
None

Events of Interest
None

2.9 Fuel Cycle Process

2.9.1 Ten-Year Data

Figure 9 displays the annual number and trend of FCP events that occurred during the 10-year period. This figure differs from those in previous sections of this report because FCP events are only associated with NRC-regulated facilities (not Agreement State-regulated). Additionally, unlike the other event types, NMED incorporates a dual use of the FCP event type; one use (Unique FCP) is for events unique to the fuel cycle process (such as a degradation of criticality controls), while the other use (Other FCP) is for any event occurring at a fuel cycle process facility (such as a lost calibration source).

The trend analysis determined that the data does not represent statistically significant trends in the number of events (indicated by the absence of trend lines). Therefore, variations within those annual values represent random fluctuation around the average of the data.

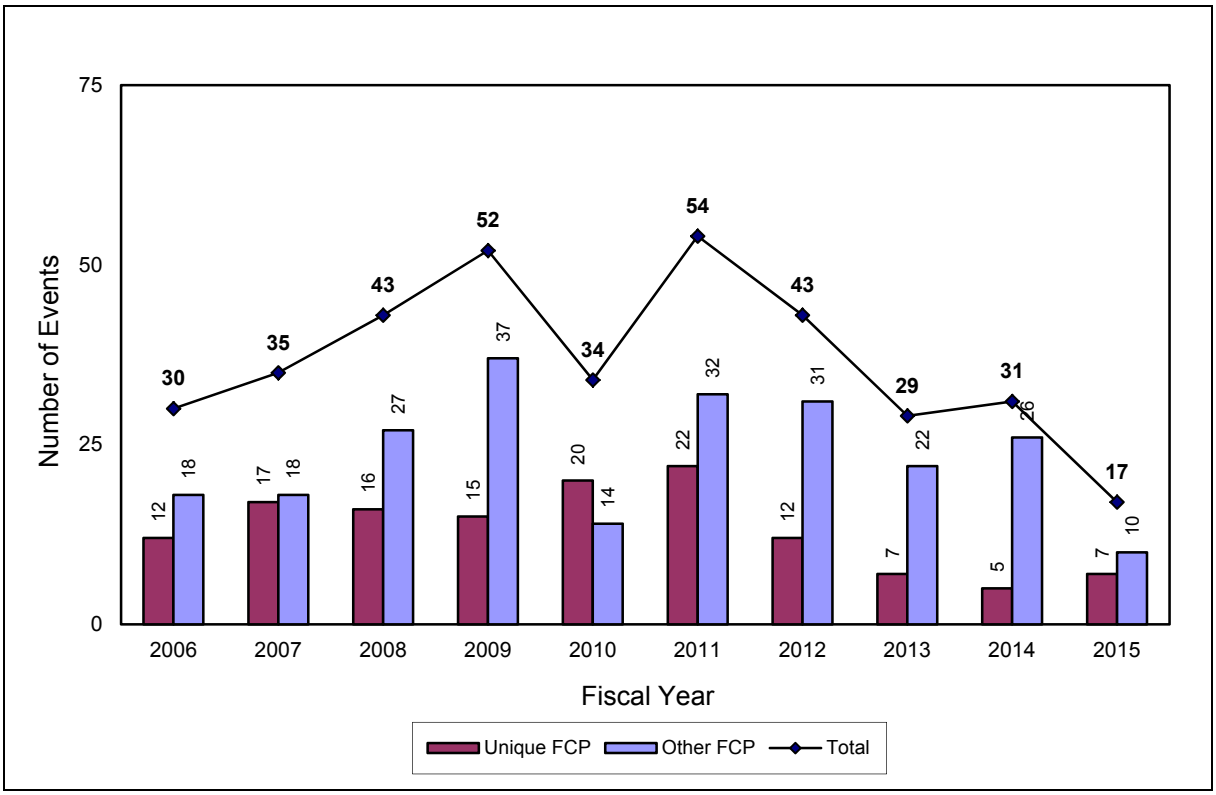

Figure 9. Fuel Cycle Process Events (368 total)

The remainder of this section will limit discussion to only those Unique FCP events (133 events).

The significance of individual FCP events may be determined by the CFR reporting requirement applicable to the event. For example, an event that is required to be immediately reported is typically more significant than an event with a 24-hour reporting requirement. For this report, those events requiring immediate reporting are considered significant. Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

Table 8 displays the number of events based on the different reporting requirement time categories. Note that each event is counted only once. If more than one reporting requirement applied to an event, the event is counted in only the most restrictive category.

Table 8. Unique FCP Events Classified by CFR Reporting Requirement

	Fiscal Year										
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Immediate	3	5	3	3	1	1	2	2	4	1	**25**
24-Hour	9	12	13	12	19	21	10	5	1	6	**108**
Total	**12**	**17**	**16**	**15**	**20**	**22**	**12**	**7**	**5**	**7**	**133**

2.9.2 FY15 Data

Seven Unique FCP events occurred in FY15, one of which was considered significant.

Significant Events - Immediate Reports

Item Number 140755 - A nuclear fuel manufacturer reported that a check valve [an Item Relied On For Safety (IROFS)] on a steam supply subsystem failed an annual preventive maintenance test on 10/20/2014. The check valve did not adequately seal, which caused it to fail to prevent backflow into an unfavorable geometry steam boiler. The boiler was down at the time and the system remained down until compensatory actions were in place such that the check valve was not needed to meet the performance criteria. The check valve had likely been in that condition for more than eight hours, leaving only one additional IROFS in place to prevent reverse flow of uranium-bearing solution into the steam separator. The safety impact of this incident is low. An apparent cause analysis was initiated. Interim corrective actions included isolating the heat exchanger from the system using blind flanges and by locking the inlet and outlet valves closed. The manufacturer plans to replace the check valve with a different and more reliable passive/active engineered IROFS by 4/30/2015. This event was classified as an EQP and FCP event.

Events of Interest

Item Number 150055 - A nuclear fuel manufacturer reported the identification of an unanalyzed condition regarding clean-out activities in the uranium recovery area. On 1/9/2015, the Low Level Dissolver was shut down to perform a routine cleanout of the enclosure. Operators scraped the uranium-bearing material into four to five piles, contrary to the intent of a requirement to scrape or sponge the material into bottles less than or equal to 2.5 liters in volume; some of the piles had volumes exceeding the 2.5 liter limit. However, spacing between the piles was at least 15 inches and the net weight of each pile was less than the 7 kg limit for material of unknown U-235 content; non-destructive assay measurements determined that the U-235 content for each pile ranged from 6.5 to 20.8 grams, with a total mass of 74.5 grams. An NRC inspection determined that this event presented a situation where multiple controls were rendered ineffective due to a single upset that had not been analyzed. It was determined that the procedure for clean-out activities lacked sufficient clarity to ensure that the material would be collected in the appropriate bottles rather than being piled. Corrective actions included suspending clean-out activities until a safety basis was developed, additional oversight, revision of the Integrated Safety analysis, and development of a new IROFS.

Item Number 150575 - A nuclear fuel manufacturer reported that workers may have exceeded controls for criticality safety in a production line glovebox. Two separate administrative Items Relied on for Safety (IROFS) are used to prevent inadvertent criticality in the glovebox; one involves limiting fissile material mass and the other involves limiting moderating material mass. These administrative controls are implemented by the use of a fissile and moderator material mass log and a three-tier station limit to verify that these masses remain within safe limits. During a routine audit on 9/16/2015, anomalies were identified in the log. The anomalies indicated that on 7/13 and 7/14/2015, the safe moderating material mass limit may have been exceeded. During a critique meeting on 9/18/2015, it was determined that the operators involved at the time of the anomalous log entries thought they needed to adhere only to the

fissile material mass limit or the moderating material mass limit, not both limits. Operations in the area, and in four areas with similar controls, were immediately suspended pending further investigation. On 9/19/2015, this event was reported to the NRC. On 9/23/2015, the report to the NRC was amended to include an additional glovebox with similar log anomalies. Operations in four of the five gloveboxes were subsequently restarted. The NRC initiated a special inspection of this event on 9/25/2015. This event was caused by inadequate training of the operators. Corrective actions included implementation of an over-check by a second operator for each log entry and a daily over-check by a manager or engineer, standardization of logs with a revision to include specific instructions, implementing computer-based logs, and personnel training.

2.9.3 Events Recently Added to NMED That Occurred Prior to FY15

No Unique FCP events were recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. Note that this data may differ from the associated Appendix D graph, which displays the number of events (all FCP events, not just Unique FCP events) added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events
None

Events of Interest
None

2.10 Other

2.10.1 Ten-Year Data

Figure 10 displays the annual number of OTH events that occurred during the 10-year period. Because OTH events do not fit a defined criterion that ensures consistency within the data, trending analysis is not performed on this data.

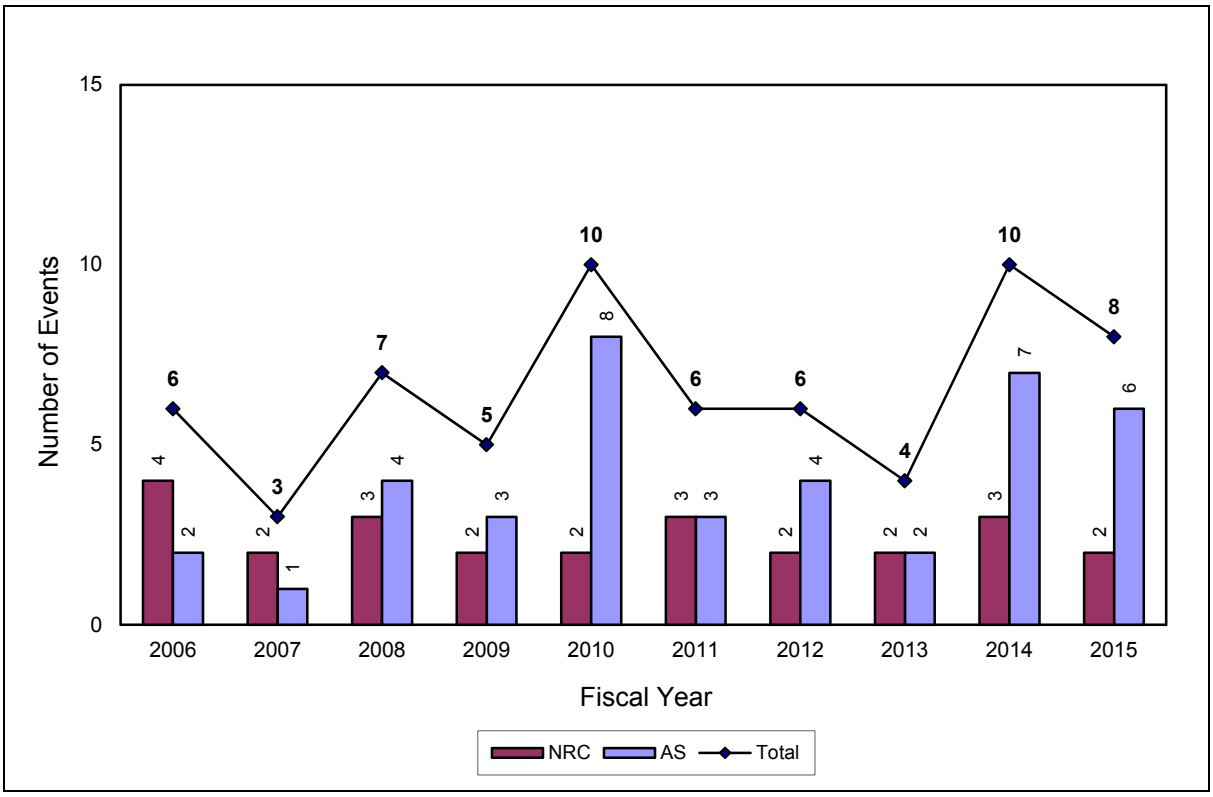

Figure 10. Other Events (65 total)

It is not possible to discern the significance of OTH events strictly from the CFR reporting requirements (as in Sections 2.4, 2.5, and 2.9). Therefore, event significance will be determined on an event-by-event basis based on the severity of the event (e.g., significant exposure to workers, members of the public, and/or the environment). Events possessing one or more unusual aspects, but that do not meet the significant event threshold, are considered events of interest.

2.10.2 FY15 Data

Eight OTH events occurred in FY15, one of which was considered significant.

Significant Events

Item Number 150027 - A pregnant patient received a thyroid ablation treatment involving 3.6 GBq (97.3 mCi) of I-131 on 12/11/2014. A pregnancy test performed on the day of treatment revealed negative results. On 12/29/2014, the patient suspected that she was pregnant and performed a home pregnancy test, which was positive. The patient reported to a clinic for a serum pregnancy test the same day, which was also positive. On 12/31/2014, the patient notified her endocrinologist that she was pregnant on the day of treatment. The endocrinologist notified the medical center the same day. The gestational age of the embryo/fetus was determined to be between two and four weeks at the time of treatment. The patient was informed of the radiation exposure to her embryo/fetus on 12/31/2014. A medical consultant calculated a dose of 26.6 cGy (rad) to the embryo/fetus, with an effect of either miscarriage or survival without malformation. As of 2/6/2015, an uneventful pregnancy was proceeding. This event was caused

by a faulty pregnancy test kit and the patient's lack of awareness that she was pregnant. Corrective actions included revising the patient questionnaire, patient instructions, and radiation safety training program. This event was classified as a potential AO.

Events of Interest

Item Number 140671 - A polymer manufacturer reported a potential radiation overexposure to five non-occupational workers. Cleaning and maintenance work began on a tank on 10/26/2014. On 10/28/2014, a supervisor noticed that the indicator for a nuclear level gauge, which contained a 37 GBq (1 Ci) Cs-137 source (assay date of 1993), showed that the shutter was in the open position. The five workers were in the area performing cleaning and maintenance operations. The workers would have crossed through the radiation field while using the access ladder to gain entry to the tank. The Ohio Bureau of Radiation Protection responded to the site on 10/29/2014. It was determined that one individual performed work in or near the radiation field for approximately 15 minutes, at a distance of about 12 inches from the gauge. The gauge manufacturer was contacted to assist with dose reconstruction. The highest exposure received by a non-occupational worker was 0.54 mSv (54.27 mrem). The Bureau concurred with that estimate. The cause of the incident was determined to be defective or inadequate procedures. Corrective actions included procedure modifications and providing additional training to personnel.

Item Number 150060 - A radiography services company reported that an attempted theft of radiographic equipment occurred on 1/24 and 1/25/2015. The company has video footage of thieves attempting to gain access to licensed material. However, all radioactive material was accounted for. Missing items included ultrasonic testing equipment, computers, and vehicle keys. Company files had also been ransacked (including sensitive information). Local police and the Federal Bureau of Investigation were notified of the incident and investigated. The Kansas Department of Health and Environment investigated the incident on 1/27/2015. No violations were identified. The company installed additional security cameras, additional motion detectors, replaced vehicle ignition switches, and contacted the property owner to discuss installation of a perimeter security fence. They will also relocate sensitive security information to a secured storage area.

Item Number 150150 - An oil company reported that a fixed nuclear gauge shutter had not been closed prior to maintenance work performed on 3/4/2015. The gauge contained a 7.4 GBq (200 mCi) Cs-137 source (assayed 6/1995). Two workers entered a confined space near the fixed gauge; one remained for 90 minutes and the other for only nine minutes. The company conducted radiation surveys in the work area and identified between 0.5 and 4 mR/hour. Utah Division of Radiation Control inspectors responded to the site to investigate. Confirmatory surveys of the work area revealed between 0.97 and 2 mR/hour. Corrective actions included purchasing a new radiation detection instrument, adding the fixed gauge/source to the lock-out list, and training appropriate personnel on the proper technique to close and lock source shutters.

Item Number 150378 - A radiography services company reported that the cab of their radiography truck was broken into. The passenger side window was broken sometime between 2300 on 5/4/2015 and 0630 on 5/5/2015. The darkroom showed no signs of attempted entry. The darkroom contained a radiography exposure device that held a 1.63 TBq (44 Ci) Ir-192 source. The device was not disturbed and radiation surveys confirmed source location. The licensee stated that the vehicle alarm system did not alarm and appeared to still be armed following the event. The licensee maintained security of the device and source until a replacement truck was delivered.

Item Number 150475 - A radiography services company reported an attempted break-in to a radiography truck that was parked overnight at a hotel in Westminster, Colorado, on 8/15/2015. The radiography darkroom contained an exposure device with a 1.44 TBq (39 Ci) Ir-192 source. Evidence of the attempted break-in was identified on the morning of 8/16/2015. The radiographers stated that the door to the darkroom had been tampered with. The door had not been breached and the alarm never activated. All radioactive material was accounted for. The Westminster Police were called and a report was filed.

Item Number 150586 - A radiography services company reported that an individual attempted to force entry into a truck's radiography darkroom, which contained a radiography exposure device and 3.7 TBq (100 Ci) Ir-192 source. The incident occurred on 6/18/2015 while the truck was parked at a hotel in Meriden, Connecticut. The two radiographers were sitting on the hotel's back patio when they heard the darkroom alarm chirp twice. A radiographer went to the truck and observed an individual standing on the bumper of the truck trying to break into the darkroom with a screwdriver. The burglar was scared off and then returned to retrieve his rental van and sped off. The Meriden Police Department was notified, an officer was dispatched, and a police report was filed. The darkroom was checked to ensure that the locks were secure and the alarm system was operable.

Item Number 150587 - A biotechnology company abandoned an irradiator in a facility in Philadelphia. The irradiator contained 15.24 TBq (411.91 Ci) of Cs-137. The company was one year behind on their rent payment and was about to be evicted from the property. The facility landlord had no knowledge of the irradiator, entered the building on 5/27/2015 and began changing all of the locks, giving himself access to the irradiator. The alarms were triggered and the local law enforcement agency responded to the facility. The Pennsylvania Department of Environmental Protection was contacted and performed an emergency inspection. They confirmed that the Cs-137 source was present in the irradiator. The Department allowed the company to retain their license, provided that they settle with the landlord and secure a letter of credit as financial assurance. The company modified their procedures to prevent future occurrence. This event was classified as an LAS and OTH event.

2.10.3 Events Recently Added to NMED That Occurred Prior to FY15

One OTH event was recently added to NMED that occurred prior to the current fiscal year and had not been included in any previous annual report. This event was not considered significant. Note that this data may differ from the associated Appendix D graph, which displays the number of events added and subtracted from specific years within the most recent 10-year period, including events moved between years due to changes in the recorded event date.

Significant Events
None

Events of Interest
None

Appendix A

Event Type Descriptions and Criteria

Appendix A
Event Type Descriptions and Criteria

The NMED events covered by this report are divided into the following categories based on the event reporting requirements defined in 10 CFR. Note that the tables in this appendix do not contain the full text of the applicable CFRs.

Lost/Abandoned/Stolen Material (LAS)

The LAS event category includes those events where licensed radioactive material is lost or found, abandoned or discovered, and stolen or recovered. The radioactive material involved can be sealed or unsealed material, specifically or generally licensed, exempt or non-exempt quantities, involve a licensee or a non-licensee, and can be found anywhere.

NMED LAS reportable events are those that meet the reporting requirements of 10 CFR Part 20.2201. Events that do not meet the 20.2201 reporting requirement thresholds are captured as not-reportable LAS events. Additionally, LAS events involving non-Atomic Energy Act material are entered into NMED as not-reportable events.

All reportable LAS events will be coded as one of the following reporting requirements. For events involving more than one source, the decision of 10 × or 1,000 × the 10 CFR Part 20 Appendix C quantity is based on the aggregate quantity of licensed material.

Table A-1. Primary LAS Reporting Requirements

Primary LAS Reporting Requirements	Reporting Requirement Summary
20.2201(a)(1)(i)	Aggregate activity ≥ 1,000 × 10 CFR Part 20 Appendix C quantity
20.2201(a)(1)(ii)	Aggregate activity > 10 and < 1,000 × 10 CFR Part 20 Appendix C quantity
39.77(d)	Irretrievable well logging source

The following additional (secondary) CFRs will be added as applicable.

Table A-2. Secondary LAS Reporting Requirements

Secondary LAS Reporting Requirements	Reporting Requirement Summary
30.55(c)	Theft/diversion of 10 Ci (or 100 Ci per year) of H 3 (not generally licensed).
37.57(a)	Unauthorized entry resulted in actual or attempted theft, sabotage, or diversion of a category 1 or category 2 quantity of material.
37.57(b)	Suspicious activity related to possible theft, sabotage, or diversion of a category 1 or category 2 quantity of material
37.81(a)	A shipment of category 1 quantities of material is lost or missing.
37.81(b)	A shipment of category 2 quantities of material is lost or missing.
37.81(c)	Actual or attempted theft or diversion (or related suspicious activities) of a shipment of category 1 quantities of material.
37.81(d)	Actual or attempted theft or diversion (or related suspicious activities) of a shipment of category 2 quantities of material.
37.81(e)	Recovery of any lost or missing shipment of category 1 quantities of material.
37.81(f)	Recovery of any lost or missing shipment of category 2 quantities of material.
39.77(b)	Loss/theft of well logging sources.
40.64(c)(1)	Theft/diversion of 15 lbs (or 150 lbs per year) of source material (uranium or

	thorium).
73.71(a)(1)	Lost shipment of any SNM.
73.App G(I)(a)(1)	Actual or attempted theft or unlawful diversion of SNM.
74.11(a)	Loss, theft or unlawful diversion (actual or attempted) of SNM or the unauthorized production of enriched uranium.
76.120(a)(2)	Loss, other than normal operating loss, of special nuclear material.
76.120(a)(3)	Actual or attempted theft or unlawful diversion of special nuclear material.
150.16(b)(1)	Actual or attempted theft or unlawful diversion of SNM.
150.17(c)(1)	Attempted theft or unlawful diversion of more than 6.8 kg (15 lb) of Uranium or Thorium at any one time or more than 68 kg (150 lb) in any one calendar year.
150.19	Theft/diversion of 10 Ci (or 100 Ci per year) of H-3 (not generally licensed). Note: This requirement is just like 30.55(c), but applies to Agreement States and offshore waters.

Medical (MED)

MED events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-3. MED Reporting Requirements

MED Reporting Requirements	Reporting Requirement Summary
35.3045(a)(1)(i)	Total dose delivered that differs from the prescribed dose by 20% or more; and differs from the prescribed dose by more than 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE.
35.3045(a)(1)(ii)	Total dosage delivered differs from prescribed by 20% or more or falls outside the prescribed range; and results in a dose that differs from prescribed by more than 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE.
35.3045(a)(1)(iii)	Fractionated dose delivered that differs from the prescribed dose for a single fraction by 50% or more; and differs from the prescribed dose by more than 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE.
35.3045(a)(2)(i)	Administration of a wrong radioactive drug containing byproduct material that results in a dose that exceeds 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE.
35.3045(a)(2)(ii)	Administration of a radioactive drug containing byproduct material by the wrong route of administration that results in a dose that exceeds 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE to the skin.
35.3045(a)(2)(iii)	Administration of a dose or dosage to the wrong individual or human research subject that results in a dose that exceeds 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE to the skin.
35.3045(a)(2)(iv)	Administration of a dose or dosage delivered by the wrong mode of treatment that results in a dose that exceeds 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE to the skin.
35.3045(a)(2)(v)	Leaking sealed source that results in a dose that exceeds 0.05 Sv (5 rem) EDE, 0.5 Sv (50 rem) to an organ or tissue, or 0.5 Sv (50 rem) SDE to the skin.
35.3045(a)(3)	Dose to the skin, organ, or tissue, other than the treatment site, that exceeds the prescribed dose by 0.5 Sv (50 rem) and 50% or more (excluding permanently implanted seeds that migrated from the treatment site).
35.3045(b)	Event resulting from patient intervention in which the administration of byproduct material or radiation from byproduct material results in unintended permanent functional damage to an organ or a physiological system, as determined by a physician.

Events are not considered MED events if they involve:

- Only a linear accelerator,
- Doses administered in accordance with a written directive (even if the directive is in error), or
- Patient intervention.

Events are considered MED events if, for example, a linear accelerator is used for therapy by mistake instead of a teletherapy unit or a teletherapy unit instead of a linear accelerator.

For purposes of determining whether to categorize an event as MED or EXP, MED events occur to patients only (i.e., those being administered a medical procedure). For example, if a patient receives too much dose during a procedure, the event would be categorized as MED rather than EXP. However, radiation exposure received from a cause other than the patient's medical procedure may be categorized as EXP.

Radiation Overexposure (EXP)

EXP events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-4. EXP Reporting Requirements

EXP Reporting Requirements	Reporting Requirement Summary
20.2202(a)(1)(i)	An individual received a total effective dose equivalent of 25 rem (0.25 Sv) or more.
20.2202(a)(1)(ii)	An individual received a lens dose equivalent of 75 rem (0.75 Sv) or more.
20.2202(a)(1)(iii)	An individual received a shallow-dose equivalent to the skin or extremities of 250 rad (2.5 Gy) or more.
20.2202(b)(1)(i)	Loss of control of material causing or threatening to cause an individual to receive a total effective dose equivalent exceeding 5 rem (0.05 Sv) in a period of 24 hours.
20.2202(b)(1)(ii)	Loss of control of material causing or threatening to cause an individual to receive an eye dose equivalent exceeding 15 rem (0.15 Sv) in a period of 24 hours.
20.2202(b)(1)(iii)	Loss of control of material causing or threatening to cause an individual to receive a shallow-dose equivalent to the skin or extremities exceeding 50 rem (0.5 Sv) in a period of 24 hours.
20.2203(a)(2)(i)	Doses in excess of the occupational dose limits for adults in 20.1201.
20.2203(a)(2)(ii)	Doses in excess of the occupational dose limits for a minor in 20.1207.
20.2203(a)(2)(iii)	Doses in excess of the limits for an embryo/fetus of a declared pregnant woman in 20.1208.
20.2203(a)(2)(iv)	Doses in excess of the limits for an individual member of the public in 20.1301.
20.2203(a)(2)(v)	Doses in excess of any applicable limit in the license.

The EXP event category includes all regulatory overexposures of radiation workers or exposures of members of the public to radiation. The overexposure can be external or internal and can be whole body, extremity, skin, lens of the eye, or internal dose. When the overexposure involves multiple individuals or an individual with multiple overexposure types (such as whole body and extremity), the different types of overexposures are entered separately. Note that dosimeters record exposure if improperly stored near a radiation source and, depending on the type of dosimeter, may react as though they are in a radiation field when exposed to heat or humidity. It is NRC policy to classify only those events that positively involve a personnel overexposure, and not just a dosimeter exposure, as reportable EXP events. For example, either the licensee does not contest the personnel overexposure, or in cases where the licensee does contest the overexposure, the State or NRC determines the event to be personnel overexposure.

EXP limits do not apply to patients receiving medical procedures.

Release of Licensed Material or Contamination (RLM)

RLM events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-5. RLM Reporting Requirements

RLM Reporting Requirements	Reporting Requirement Summary
20.2202(a)(2)	Release of radioactive material, inside or outside of a restricted area, so that had an individual been present for 24 hours, the individual could have received an intake 5 times the ALI.
20.2202(b)(2)	Release of material, inside or outside of a restricted area, so that, had an individual been present for 24 hours, the individual could have received an intake in excess of 1 ALI.
20.2203(a)(2)(vi)	Doses in excess of the ALARA constraints for air emissions established under 20.1101(d).
20.2203(a)(3)(i)	Radiation or concentrations of radioactive material in a restricted area in excess of any applicable limit in the license.
20.2203(a)(3)(ii)	Radiation or concentrations of radioactive material in an unrestricted area in excess of 10 times any applicable limit set forth in Part 20 or in the license.
20.2203(a)(4)	Levels of radiation or releases of radioactive material in excess of the standards in 40 CFR Part 190, or of license conditions related to those standards.
30.50(a) 40.60(a) 70.50(a) 76.120(b)	Event that prevents immediate protective actions necessary to avoid exposures to radiation or radioactive materials that could exceed regulatory limits or releases of material that could exceed regulatory limits.
30.50(b)(1) 40.60(b)(1) 70.50(b)(1) 76.120(c)(1)	Unplanned contamination event that requires access to be restricted for > 24 hours, involves > 5 times the lowest ALI, and has access restricted for a reason other than to allow isotopes with a half-life of < 24 hours to decay.
30.50(b)(3) 40.60(b)(3) 70.50(b)(3) 76.120(c)(3)	Event that requires unplanned medical treatment at a medical facility of an individual with spreadable radioactive contamination on the individual's clothing or body.
50.72(b)(3)(xii) 72.75(c)(3)	Event requiring the transport of a radioactively contaminated person to an offsite medical facility for treatment.

The RLM event category includes two types of events. The first type is a radioactive release to air or water exceeding the 10 CFR Part 20 Appendix B annual limit on intake (ALI). The second type of RLM event involves contamination events such as a radioactive spill outside of work areas, removable contamination found on equipment, or material tracked around a laboratory such that additional radiological control measures had to be implemented. This category does not include spills inside of laboratory hoods, radiopharmaceutical dose preparation areas, or hot cells where radioactive work routinely requires cleanup or changing of absorbent paper after the performance of a task. Should there be multiple release types (e.g., surface, air, water, or person) or areas of contamination associated with the release, this information is entered individually.

Leaking Sealed Source (LKS)

LKS events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-6. LKS Reporting Requirements

LKS Reporting Requirements	Type of Source
31.5(c)(5)	Generally licensed
34.27(d)	Radiography
35.67(e)	Medical
39.35(d)(1)	Well logging (leaking)
39.77(a)	Well logging (ruptured)
30.50(b)(2)	All other sources

The NRC requires that most sealed sources be periodically leak tested to verify that the material is still sealed and that the source is still considered safe to use without contamination controls, including protective clothing or gloves. Sources are generally exempt from leak testing under the following conditions [see 10 CFR Part 31.5(c)(2), 34.27(c), 35.67(f), and 39.35(e)]:

- Sources containing only gaseous radioactive material (like H-3, Kr-85, etc.),
- Sources containing licensed material with a half-life of 30 days or less,
- Sources containing <= 100 μCi of other beta and/or gamma emitting material,
- Sources containing <= 10 μCi of alpha emitting material,
- Sources held in storage in the original shipping container prior to initial installation,
- Seeds of Ir-192 encased in nylon ribbon, or
- Sources in storage and not in use (must be leak tested prior to use or transfer).

A source is considered leaking if a leak test can detect greater than 0.005 μCi of removable radioactive material. The leaking source is then removed from service, disposed of or returned to the manufacturer for repair, and a report is sent to the NRC or Agreement State with the details of the leaking source.

For regulatory reporting purposes, a leaking source is generally considered a failed device under 10 CFR Part 30. Therefore, in most cases an LKS event is also coded as an EQP event. An exception is the Ni-63 foil source, which is coded as only an LKS event.

Equipment (EQP)

EQP events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-7. EQP Reporting Requirements

EQP Reporting Requirements	Reporting Requirement Summary
21.21(d)(1)(i)	A failure to comply or a defect affecting the construction or operation of a facility or an activity that is subject to licensing requirements.
21.21(d)(1)(ii)	A failure to comply or a defect affecting a basic component that is supplied for a facility or an activity that is subject to licensing requirements.
30.50(a) 40.60(a) 70.50(a) 76.120(b)	Event that prevents immediate protective actions necessary to avoid exposures to radiation or radioactive materials that could exceed regulatory limits or releases of material that could exceed regulatory limits.
30.50(b)(2) 40.60(b)(2) 70.50(b)(2) 72.75(d)(1) 76.120(c)(2)	Equipment is disabled or fails to function as designed.
30.50(b)(4) 40.60(b)(4) 70.50(b)(4) 76.120(c)(4)	Unplanned fire or explosion that damages any licensed material or any device, container, or equipment containing licensed material.
31.5(c)(5)	Actual or indicated failure to shielding, the on-off mechanism or indicator, or upon the detection 0.005 uCi or more of removable radioactive material.
34.101(a)(1)	Unintentional disconnection of the radiographic source assembly from the control cable.
34.101(a)(2)	Inability to retract and secure the radiographic source assembly to its fully shielded position.
34.101(a)(3)	Failure of any radiographic component (critical to the safe operation of the device) to properly perform its intended function.
36.83(a)(1)	An irradiator source stuck in an unshielded position.
36.83(a)(2)	Fire or explosion in an irradiator radiation room.
36.83(a)(3)	Damage to the irradiator source racks.
36.83(a)(4)	Failure of the irradiator cable or drive mechanism used to move the source racks.
36.83(a)(5)	Inoperability of the irradiator access control system.
36.83(a)(6)	Detection of irradiator source by the product exit monitor.
36.83(a)(7)	Detection of irradiator radioactive contamination attributable to licensed radioactive material.
36.83(a)(8)	Structural damage to the irradiator pool liner or walls.
36.83(a)(9)	Abnormal water loss or leakage from the irradiator source storage pool.
36.83(a)(10)	Irradiator pool water conductivity exceeding 100 microsiemens per centimeter.
39.77(a)	Ruptured well logging sealed source.
72.75(c)(1)	Defect in any spent fuel, HLW, or reactor-related GTCC waste storage structure, system, or component that is important to safety.
72.75(c)(2)	Significant reduction in the effectiveness of any spent fuel, HLW, or reactor-related GTCC waste storage confinement system during use.
72.242(d)	Design or fabrication deficiency for any spent fuel storage cask delivered to a licensee which affects the ability of components important to safety to perform their safety function.

The EQP event category includes all types of radiological equipment problems, including generally licensed device problems covered in 10 CFR Part 31; radiography equipment problems covered in 10 CFR Part 34; irradiator problems covered in 10 CFR Part 36; well logging problems covered in 10 CFR Part 39, and other types of equipment covered in 10 CFR Part 30, 40, 70, and 76. EQP events are defined as the failure of, or a defect in, any piece of equipment that either contains licensed radioactive materials as an integral part, or whose function is to interact with such materials.

Transportation (TRS)

TRS events are determined and coded per the 10 CFR reporting requirements listed below.

Table A-8. TRS Reporting Requirements

TRS Reporting Requirements	Reporting Requirement Summary
20.1906(d)(1)	Transported package exceeds removable surface contamination limits.
20.1906(d)(1)	Transported package exceeds external radiation limits.
71.5	Transportation of licensed material.
71.95(a)(1)	Significant reduction in the effectiveness of any NRC-approved Type B or Type AF packaging during use.
71.95(a)(2)	Defects with safety significance in any NRC-approved Type B or fissile material packaging, after first use.
71.95(a)(3)	Conditions of approval in the Certificate of Compliance were not observed in making a shipment.
71.95(b)	Conditions in the Certificate of Compliance were not followed during a shipment.

Fuel Cycle Process

The FCP event type is used two ways. One usage is identical to the other event types in that it is used to code events involving FCP reporting requirements. However, it is also used to denote any type of event occurring at (or involving) a fuel cycle process facility. Therefore, reporting requirements other than those listed below can be used with the FCP event type. In this case, the event will be coded with multiple event types.

For those events involving only the FCP event type, the events are determined and coded per the 10 CFR reporting requirements, NRC Bulletin, and Safety Equipment Actuation requirement listed below.

Table A-9. FCP Reporting Requirements

FCP Reporting Requirements	Reporting Requirement Summary
70.52(a)	Inadvertent nuclear criticality.
70.App A(a)(1)	Inadvertent nuclear criticality.
70.App A(a)(2)	Acute intake by an individual of 30 mg or greater of uranium in a soluble form.
70.App A(a)(3)	Acute chemical exposure to an individual from licensed material or hazardous chemicals produced from licensed material that exceeds the quantitative standards established to satisfy the requirements in 70.61(b)(4).
70.App A(a)(4)(i)	Event or condition such that no IROFSs remain available and reliable to perform the safety function in accordance with 70.61(b) and 70.61(c).
70.App A(a)(4)(ii)	Event or condition such that no IROFSs remain available and reliable to prevent a nuclear criticality accident (i.e., loss of all controls in a particular sequence).
70.App A(a)(5)	Loss of controls such that only one IROFS has been available and reliable (for longer than the past eight hours) to prevent a nuclear criticality accident.
70.App A(b)(1)	Event or condition that results in the facility being in a state not analyzed, improperly analyzed, or different from that analyzed, and results in failure to meet the performance requirements of 70.61.
70.App A(b)(2)	Loss or degradation of IROFSs that results in failure to meet the performance requirement of 70.61.
70.App A(b)(3)	Acute chemical exposure to an individual from licensed material or hazardous chemicals produced from licensed materials that exceeds the quantitative standards that satisfy the requirements of 70.61(c)(4).
70.App A(b)(4)	Natural phenomenon or external event, including fires internal and external to the facility, that affected or may have affected the safety function, availability, or reliability of one or more IROFSs.
70.App A(b)(5)(i)	Occurrence of an event or process deviation that was considered in the ISA and was dismissed due to its likelihood.
70.App A(b)(5)(ii)	Occurrence of an event or process deviation that was considered in the ISA, categorized as unlikely, and whose associated unmitigated consequences would have exceeded those in 70.61(b) had the IROFSs not performed their safety function(s).
72.74(a)	Accidental criticality or any loss of special nuclear material.
76.120(a)(1)	Criticality event.
76.120(a)(4)	Emergency condition that has been declared an alert or site area emergency.

NRCB 91-01 Immediate reports: NRCB 91-01 – A 24 hour reports: NRCB 91-01 – B	The loss of criticality safety controls where (1) moderation is used as the primary criticality control, or (2) more than a safe mass of fissionable material is involved (regardless of the type of controls used to satisfy the double contingency principle), and that meet one or more of the following immediate reporting criteria: 1. Any event that results in the violation of the double contingency principle, as defined in ANSI 8.1, and where the double contingency principle cannot be re-established within 4 hours after the initial observation of the event. 2. The occurrence of any unanticipated or unanalyzed event for which the safety significance of the event or corrective actions to re- establish the double contingency principle are not readily identifiable. 3. Any case where it is determined that a criticality safety analysis was deficient and where the necessary controlled parameters were not established or maintained. 4. Any event involving a controlled parameter previously identified by the NRC or the licensee as requiring immediate reporting to the NRC and where the double contingency principle cannot be re- established within 4 hours after the initial observation of the event. All other criticality safety events that do not meet the aforementioned criteria, but still result in a violation of the double contingency principle, such as events where the double contingency principle is violated but control is immediately re-established, should be reported to the NRC within 24 hours in accordance with the commitments in the responses to the bulletin.
S.E.A	Safety equipment actuation.

Other (OTH)

The OTH event category includes the following types of events:

1. Doses to an embryo/fetus or nursing child reportable per 10 CFR Part 35.3047. Note that these events are not MED events (reportable per 10 CFR Part 35.3045).
2. Dose in an unrestricted area in excess of 2 mR/hr, but no individual received a dose in excess of limits (if a dose in excess of limits is received, the event is an EXP event).
3. 10 CFR 37 events that do not result in the actual theft, sabotage, or diversion of Category 1 or 2 quantities of radioactive material. Otherwise, the event is as an LAS event.
4. Reportable events that do not specifically fit into one of the previous event types.

For items 1-3 above, OTH events are determined and coded per the 10 CFR reporting requirements listed below. Due to the nature of item 4 above, other reporting requirements may also be used.

Table A-10. OTH Reporting Requirements

OTH Reporting Requirements	Reporting Requirement Summary
20.2203(a)(2)(iv)	Dose in an unrestricted area in excess of 2 mR/hr, but no dose received in excess of limits.
35.3047(a)	Dose to an embryo/fetus greater than 50 mSv (5 rem) DE from administration of byproduct material or radiation from byproduct material to a pregnant individual unless specifically approved, in advance, by the authorized user.
35.3047(b)(1)	Dose to a nursing child greater than 50 mSv (5 rem) TEDE resulting from an administration of byproduct material to a breast-feeding individual.
35.3047(b)(2)	Dose to a nursing child resulting in unintended permanent functional damage to an organ or physiological system, as determined by a physician, resulting from an administration of byproduct material to a breast-feeding individual.
37.57(a)	Unauthorized entry resulted in actual or attempted theft, sabotage, or diversion of a category 1 or category 2 quantity of material.
37.57(b)	Suspicious activity related to possible theft, sabotage, or diversion of a category 1 or category 2 quantity of material
37.81(c)	Actual or attempted theft or diversion (or related suspicious activities) of a shipment of category 1 quantities of material.
37.81(d)	Actual or attempted theft or diversion (or related suspicious activities) of a shipment of category 2 quantities of material.

Appendix B

Statistical Trending Methodology

Appendix B
Statistical Trending Methodology

General

The following is a general discussion of statistical trending techniques.

A common approach to the statistical analysis of trend is based on regression methods. In particular, it is often the case that a relationship exists between the values assumed by a pair of variables. For example, if x is time (in years), and y is the rate of events per year, then we could use regression methods to study whether there is a relationship between time and event rate.

Regardless of the application, it is standard practice to refer to x as the independent variable and y as the dependent variable. Another common term for the dependent variable is "response variable," and the terms covariant and explanatory variable are sometimes used for the independent variable. Also, it is typical with regression modeling that the independent variable can be measured with little or no error, but the dependent variable involves a random error. Consequently, even if there is a deterministic functional relationship between the two variables, when data pairs (x_1, y_1), (x_2, y_2),..., (x_n, y_n) are plotted, the points will not coincide exactly with the function, but instead will tend to be scattered. Such a plot is called a scatter diagram, and shows the variation in the data. The plots in this report are bar charts containing the same information.

Fitting a Straight Line to Data

Consider a linear function

$$f(x) = \alpha + \beta x \tag{B-1}$$

where α and β are unknown parameters. A common model is that y is the sum of a linear function of the form (1) and a random error term, e. Standard results on estimation and inference about the parameters of the model assume that e is a normally distributed random variable with mean 0 and constant (but unknown) variance, σ^2. These assumptions mean that:

- Each yi is an observed value of a random quantity that is normally distributed [with mean f(xi)], and
- All the observations yi are of variables with a common variance, σ2.

The y_i are also assumed to be observations of random quantities that are independent of each other.

Under these conditions, the usual approach to estimating the unknown parameters α and β is the method of least squares (LS). In this method, α and β are selected so that the sum of the squares of the vertical distances between the data points and the fitted line is as small as possible. The LS method leads to the estimates

$$\hat{\beta} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})y_i}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \text{ and} \tag{B-2}$$

$$\hat{\alpha} = \bar{y} - \hat{\beta}\bar{x}\,, \tag{B-3}$$

where $\bar{x}$ and $\bar{y}$ are arithmetic averages. The estimated LS regression line is then

$$\hat{y} = \hat{\alpha} - \hat{\beta}x\,, \tag{B-4}$$

and an estimate of σ is

$$s = \sqrt{\frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{n-2}} \; . \tag{B-5}$$

Testing for Trend

A trend exists whenever the true slope, β, is not zero. We start the analysis with the idea that β is zero, and then ask whether the data tell us otherwise. Two quantities computed from the data are used in this assessment. The first, the *error sum of squares* (SSE), appears in the numerator of s. It is defined as

$$SSE = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \; . \tag{B-6}$$

This quantity is the number that is minimized in order to find the estimates of α and β. The differences being squared in SSE represent random variations that remain after the linear fitting process. The second quantity is the *regression sum of squares* (SSR), defined by the following equation

$$SSR = \sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2 \; . \tag{B-7}$$

Note that SSR looks at deviations between the fitted line and the default notion that the data are constant and have no slope.

One can show by algebra that

$$SSE + SSR = SST \; , \tag{B-8}$$

where the *total sum of the squares* (SST), is defined as

$$SST = \sum_{i=1}^{n} (y_i - \bar{y})^2 \; . \tag{B-9}$$

SST measures the overall variation in the data. It is the numerator that would be used to estimate the variance in a sample from a normally-distributed random variable, where all the data in the sample have the same distribution (and thus no trend). This variance measures "random variation" in such a sample.

In the framework of the linear function (1), the regression's effectiveness is measured by the *SSR* term defined above. When it is small, the fitted curve will not differ very much from the horizontal line $y = \bar{y}$. *SSE* will be approximately equal to *SST*, and, from the data, both *SSE* and *SST* will be estimates of mere random variation. In this case, the data does not provide evidence that β is different from zero.

On the other hand, if the y values tend to vary linearly with respect to the independent variable, x, then some of the variation in the y values can be attributed to this dependence on x. Since *SSR* assesses the difference between the least squares predictions of the y values and the arithmetic mean, $\bar{y}$, it is a measure of the variation which is "explained" by the linear relationship. When the slope of the fitted line is large, more of these differences will tend to be large, resulting in a large value of *SSR*.

In the equation, $SST = SSE + SSR$, the total variation is partitioned into two parts, the variation due to random error and the variation due to the linear relationship. The fraction of the total variation that is due to the linear relationship is called the coefficient of determination, or r^2, and is defined by:

$$r^2 = \frac{SSR}{SST} \; . \tag{B-10}$$

r^2 is a fraction that varies from 0 to 1. It will be near 0 if most of the variation is due to randomness, and it will be near 1 if most of the variation is due to the linear relationship.

The closeness to 1 needed for the data to show that the slope is not zero depends on the number of data points. If the dependent data are independent, normally-distributed at each x, with constant variance, and no trend, then the quantity, F, defined by

$$F = \frac{(n-2)\,r^2}{1-r^2} \tag{B-11}$$

can be shown to have an F distribution with degrees of freedom 1 and $n - 2$, where n is the number of data points. When the data satisfy the assumptions except that there is a significant trend, r^2 will be closer to 1 and the computed F statistic will be much larger. Specifically, if the computed F exceeds the upper fifth percentile of the F distribution with 1 and $n - 2$ degrees of freedom, we infer that the data contain evidence that β is not zero, at the 5% level of significance. In this case, we reject the null hypothesis that $\beta = 0$ and conclude that a statistically significant trend exists, with 95% confidence.

As an example, for an assumed set of data fit to the linear model, assume the $r^2 = 0.9369$ and that n is 13. Then the calculated F is 163.3. The upper 95th percentile of the $F(1,11)$ distribution is 4.84. Since 163.3 far exceeds the upper 95th F percentile, the linear model is statistically significant. In this example, the data show that it would be very unlikely for a trend not to exist. The linear model explains too much of the variation in the data for a trend not to exist.

Applying the Model to the NMED Data

The method described above was applied for each category of NMED event data, for the overall NMED data, and for additional subgroups of data when trends were found in the overall data. When the calculated F exceeded the 95th percentile, the trend line was shown on the graph and identified as being statistically significant.

In future reports, methods slightly different than that explained above could be employed because the NMED data in many cases does not follow the assumptions listed above. In particular, three considerations apply.

- The data are counts, and thus are discrete rather than being normally distributed. This problem is most pronounced when the counts are relatively low or sparse. Also, normally-distributed data in general can be negative, but the counts are always greater than or equal to zero.
- Variations in counts tend to increase as the counts increase. If the events occur at random, with a constant occurrence rate in a particular year or quarter, then the variance of the count for that year or quarter is equal to the mean or average for that year or quarter. Thus, the assumption of a constant variance for the data in each year may not apply.
- Finally, more than one count can be associated with a single reported incident in a single event category. This situation would occur, for example, if several pieces of equipment fail in an event or if several types of overexposure occur. In these cases, the data are not independent.

One way to address the first two concerns is to identify the number of licensees in various NMED categories and study the event occurrence rates rather than the counts. The rates are more likely to come from a continuum, and might have a more constant variance.

Taking logarithms of the counts and then applying the LS method avoids the problem of possible negative trend lines. The resulting models can be converted back to the scale of the counts after the regression line is identified. In the scale of the counts, the resulting trend, if any, has a slight curvature.

Weighted regression is a method similar to the LS method described above, but it compensates explicitly for the effect of the different variances from year to year.

Another approach that deals with the first two concerns is to apply regression methods that have been designed specifically for counts. Poisson regression, for example, is based on the idea that the data in each time period are counts observed from a Poisson distribution, with an occurrence rate that is described by the model. Given occurrence rates in each time period, and independent counts, the probability of seeing the observed data is easily computed by multiplying the occurrence probabilities for the individual time periods. The slope and intercept parameter estimates are selected so that the model maximizes the resulting "likelihood function."

The third issue may have little effect on the results of a trend analysis, as long as there are many counts with relatively few occurring in clumps, no trends in the occurrence of clumps, and no large clumps of counts coming from a single occurrence report. The best way to address the dependence issue is to identify and remove the duplicate counts prior to the trend analysis.

Appendix C

IAEA Radionuclide Categorization

Appendix C
IAEA Radionuclide Categorization

Table C-1 lists the radionuclides that this report uses to determine the significance for events involving the loss, abandonment, or theft of radioactive sources. This list is derived from the IAEA *Code of Conduct on the Safety and Security of Radioactive Sources (2004)* and from IAEA Safety Guide RS-G-1.9, *Categorization of Radioactive Sources*. Based on the amount of radioactivity involved, the radionuclides are grouped into five categories, with Category 1 being the most hazardous. These categories may be summarized as follows (derived from IAEA Safety Guide RS-G-1.9, *Categorization of Radioactive Sources*):

Category 1: **Extremely dangerous.** These sources could cause permanent injury within a few minutes if handled. Doses could be fatal to someone in close proximity to an unshielded source for periods ranging from a few minutes to an hour.

Category 2: **Very dangerous.** These sources could cause permanent injury within minutes to hours if handled. Doses could be fatal to someone in close proximity to an unshielded source for periods ranging from hours to days.

Category 3: **Dangerous.** These sources could cause permanent injury within hours if handled. Doses could possibly (but unlikely) be fatal to someone in close proximity to an unshielded source for periods ranging from days to weeks.

Category 4: **Unlikely to be dangerous.** These sources would not cause permanent injury, although delayed health effects are possible. Doses could possibly (but unlikely) cause temporary injury to someone in close proximity to an unshielded source for a period of many weeks.

Category 5: **Most unlikely to be dangerous.** These sources would not cause permanent injury.

Table C-1. IAEA Code of Conduct Category 1 through 5 Radionuclide Activity Thresholds

Radionuclide	Category 1		Category 2		Category 3		Category 4		Category 5	
	TBq	Ci [1]	TBq	Ci [1]	TBq	Ci [1]	TBq	Ci [1]	TBq	Ci [1]
Am-241	60	1,622	0.6	16.2	0.06	1.62	0.0006	0.0162	1.0e-08	2.7e-07
Am-241/Be	60	1,622	0.6	16.2	0.06	1.62	0.0006	0.0162	1.0e-08	2.7e-07
Cf-252	20	541	0.2	5.4	0.02	0.54	0.0002	0.0054	1.0e-08	2.7e-07
Cm-244	50	1,352	0.5	13.5	0.05	1.35	0.0005	0.0135	1.0e-08	2.7e-07
Co-60	30	811	0.3	8.1	0.03	0.81	0.0003	0.0081	1.0e-07	2.7e-06
Cs-137	100	2,703	1.0	27.0	0.10	2.70	0.001	0.0270	1.0e-08	2.7e-07
Gd-153	1,000	27,030	10.0	270.3	1.00	27.03	0.01	0.2703	1.0e-05	2.7e-04
Ir-192	80	2,162	0.8	21.6	0.08	2.16	0.0008	0.0216	1.0e-08	2.7e-07
Pm-147	40,000	1,081,200	400.0	10,812.0	40.00	1,081.20	0.4	10.8120	1.0e-05	2.7e-04
Pu-238	60	1,622	0.6	16.2	0.06	1.62	0.0006	0.0162	1.0e-08	2.7e-07
Pu-239/Be	60	1,622	0.6	16.2	0.06	1.62	0.0006	0.0162	1.0e-08	2.7e-07
Ra-226	40	1,081	0.4	10.8	0.04	1.08	0.0004	0.0108	1.0e-08	2.7e-07
Se-75	200	5,406	2.0	54.1	0.20	5.41	0.002	0.0541	1.0e-06	2.7e-05
Sr-90 (Y-90)	1,000	27,030	10.0	270.3	1.00	27.03	0.01	0.2703	1.0e-08	2.7e-07
Tm-170	20,000	540,600	200.0	5,406.0	20.00	540.60	0.2	5.4060	1.0e-06	2.7e-05
Yb-169	300	8,109	3.0	81.1	0.30	8.11	0.003	0.0811	1.0e-05	2.7e-04

Notes

1. The primary values are given in TeraBequerel (TBq). Curie (Ci) values are provided for practical usefulness only and are rounded after conversion.

Appendix D

Revision of Data

Appendix D
Revision of Data

The NMED is a dynamic database with new reports and revisions to previous reports being added on a continuing basis. This activity can result in additions or subtractions to data that was published in previous issues of this report. Numerical changes in NMED numbers can result from several different types of technical changes to coded data. The most common types of changes to database records are:

- Record additions due to late reporting
- Record additions or subtractions due to changes in event type
- Changes between fiscal years due to event date changes on individual events
- Record additions or subtractions due to changes in event reportability
- Record additions or subtractions due to reclassifying a single combined event as multiple individual events (or vice versa)
- Record deletions due to duplicated records or NRC direction

Figures D-1 through D-10 below display the changes in the data published in the previous annual report. A positive value indicates that records were added and a negative value indicates that records were removed.

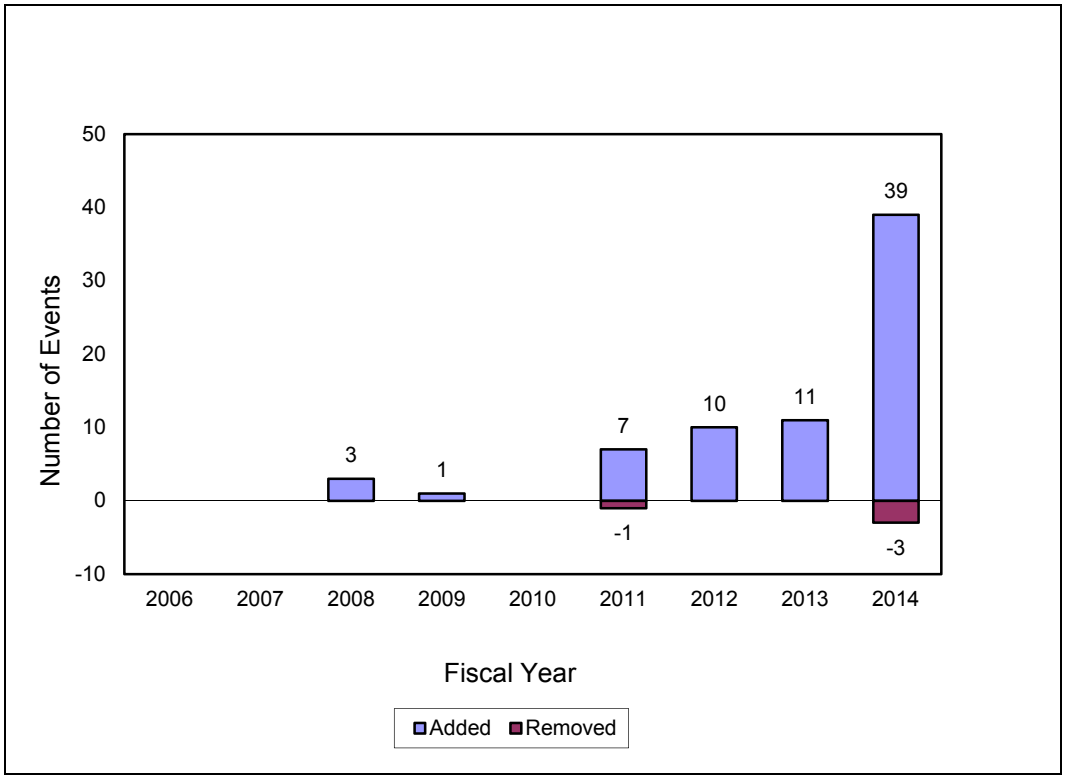

Figure D-1. Changes to All NMED Event Data

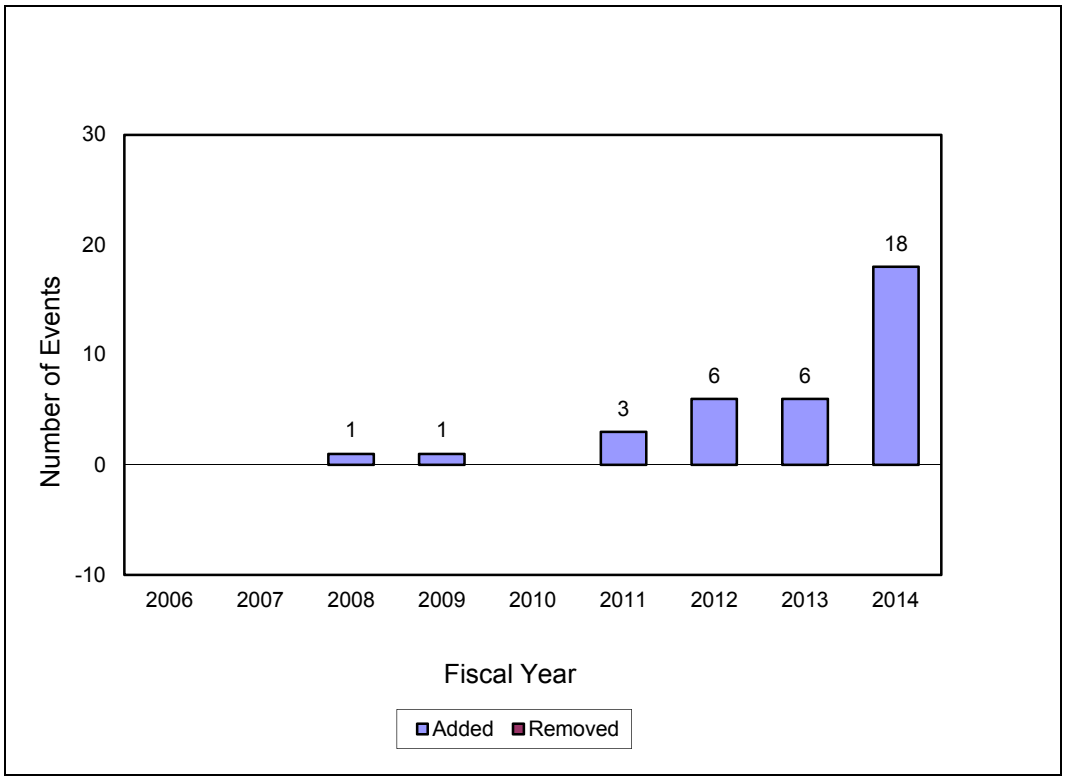

Figure D-2. Changes to LAS Data

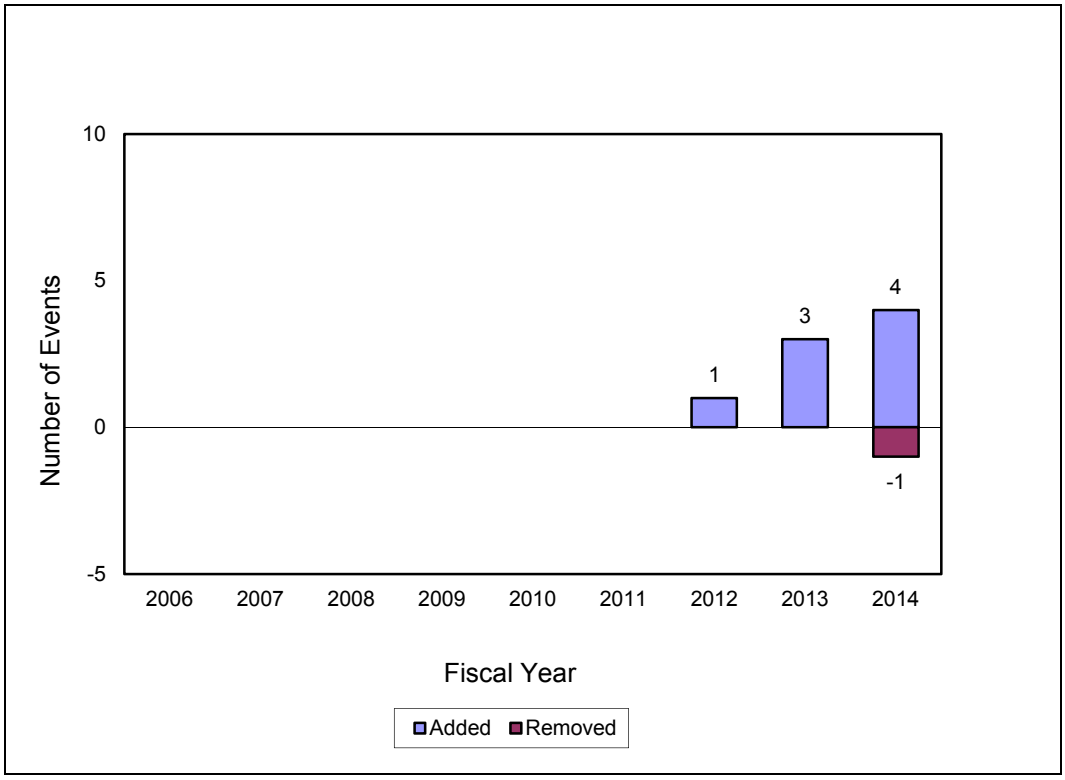

Figure D-3. Changes to MED Data

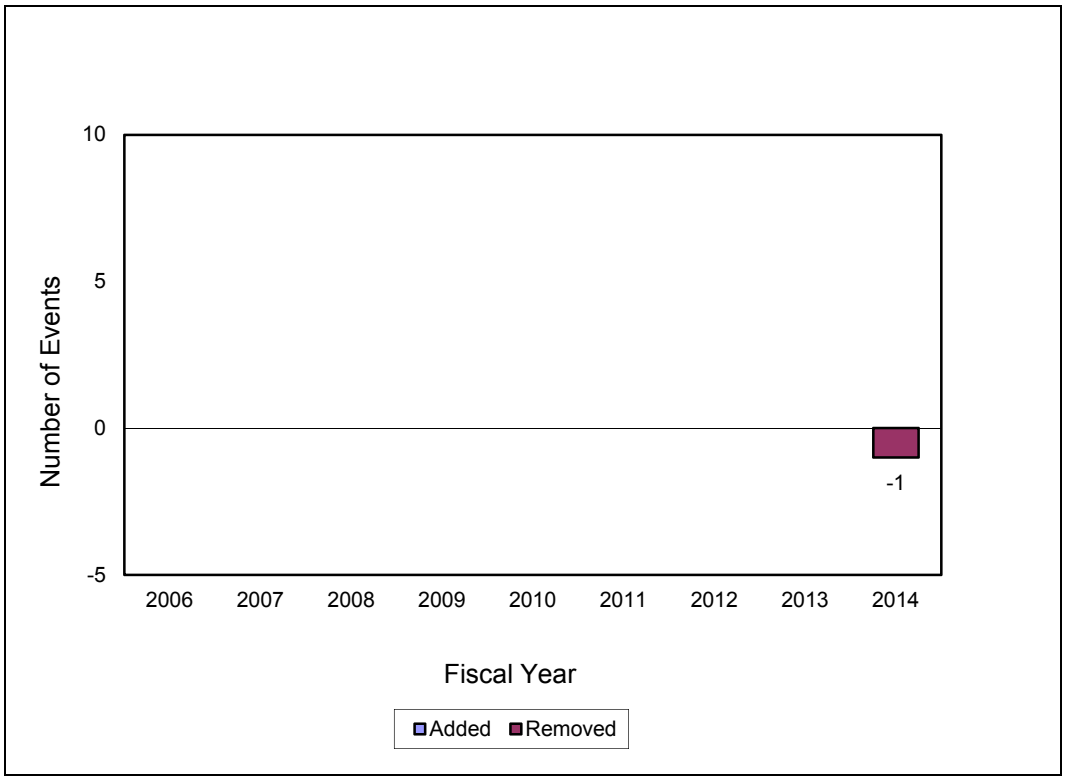

Figure D-4. Changes to EXP Data

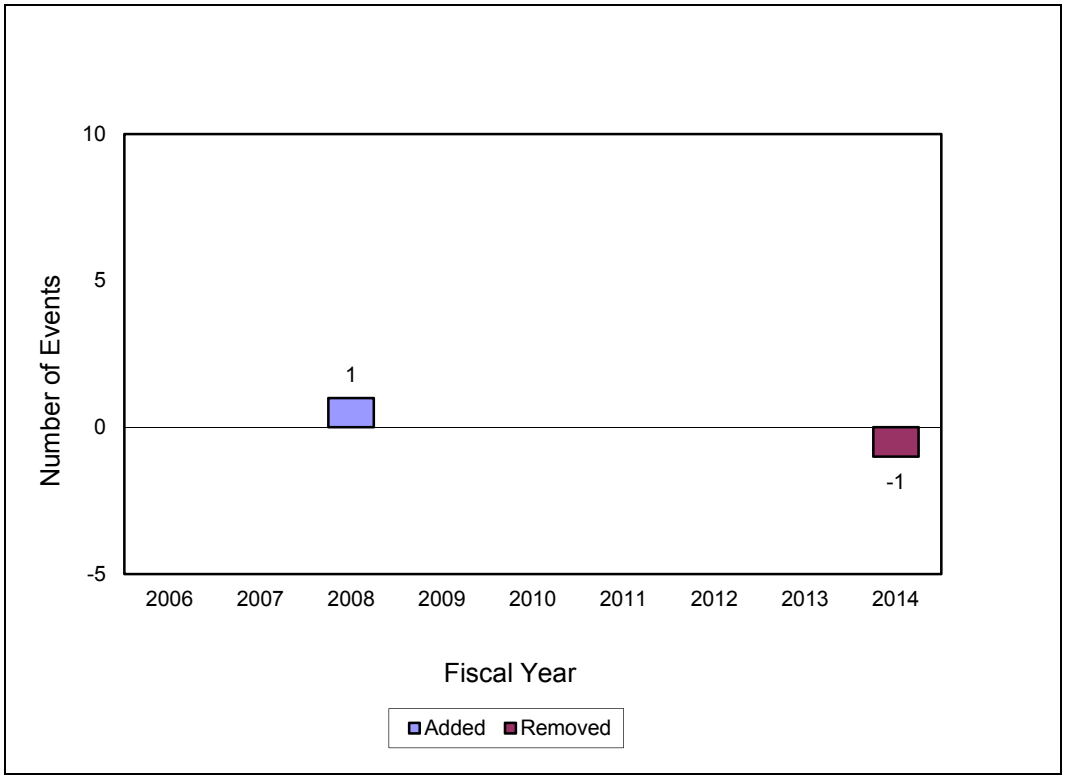

Figure D-5. Changes to RLM Data

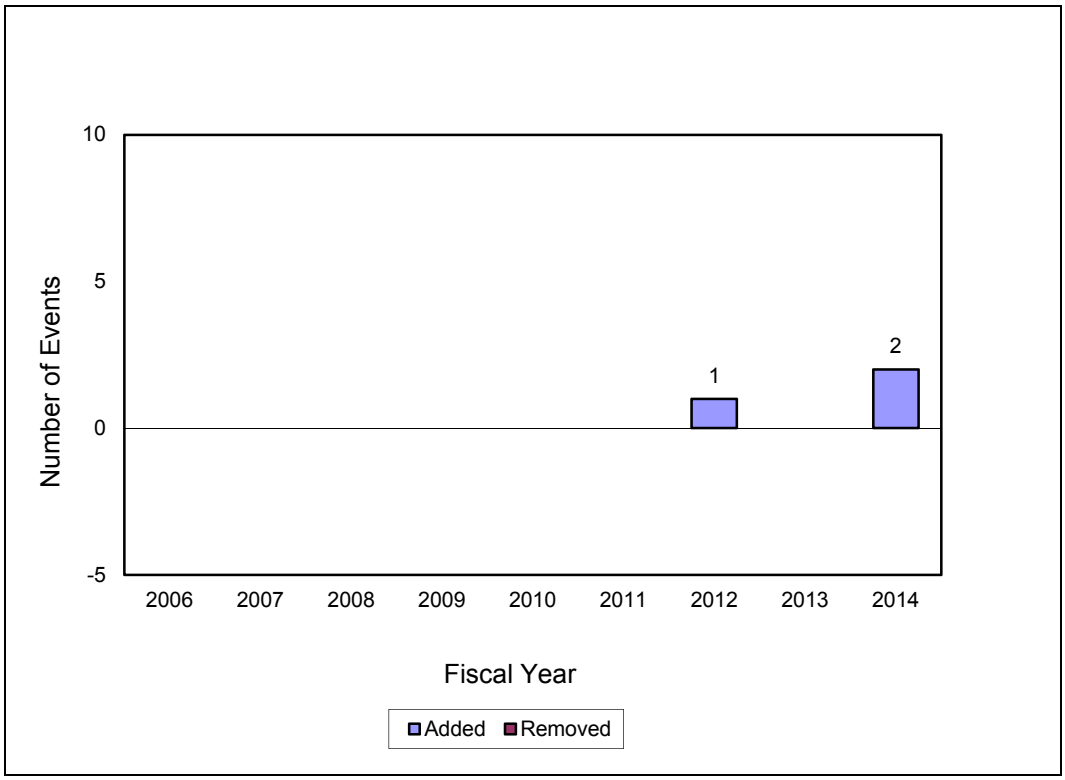

Figure D-6. Changes to LKS Data

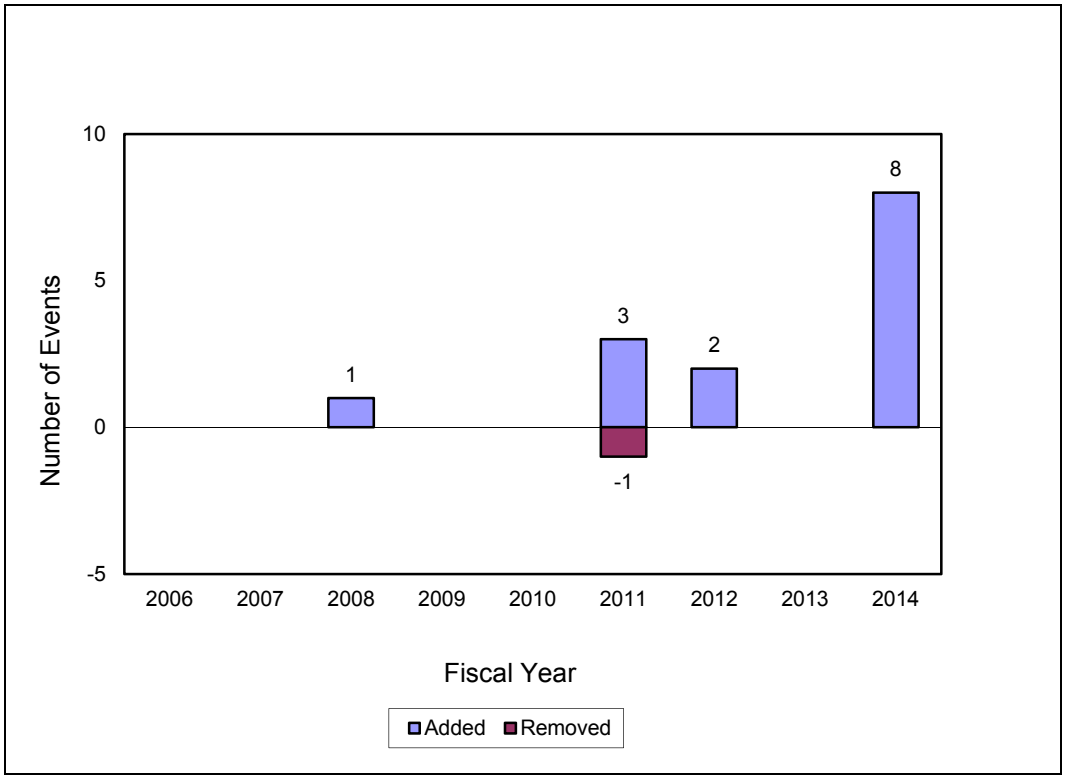

Figure D-7. Changes to EQP Data

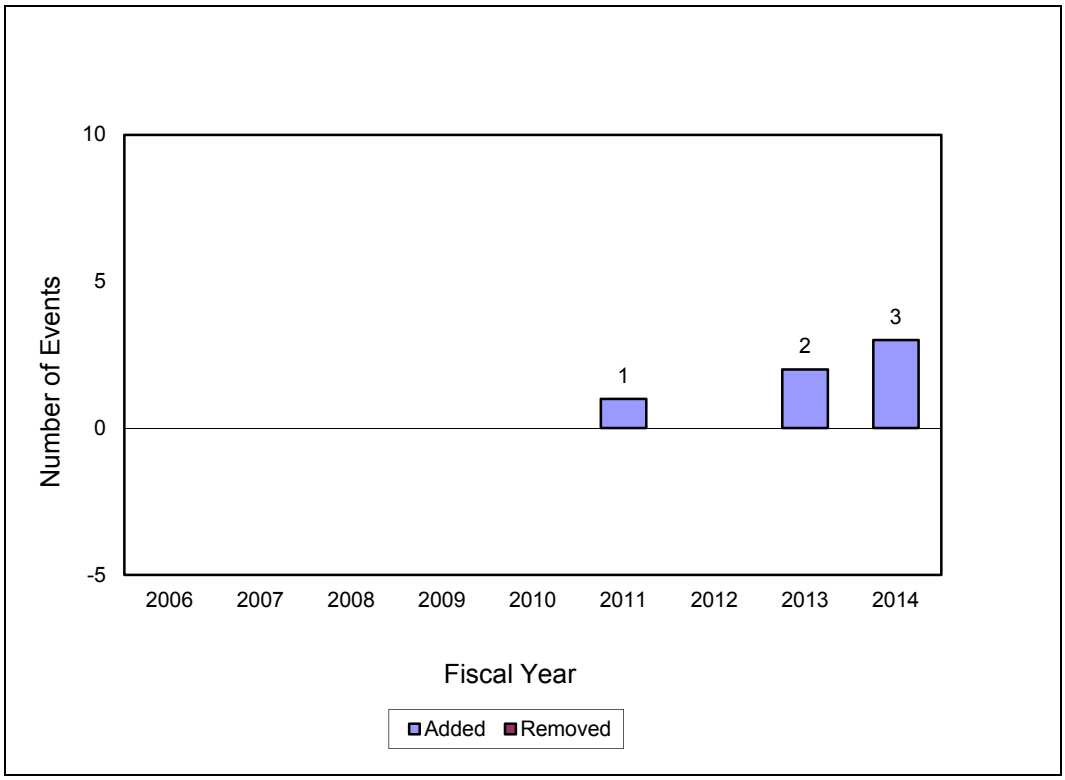

Figure D-8. Changes to TRS Data

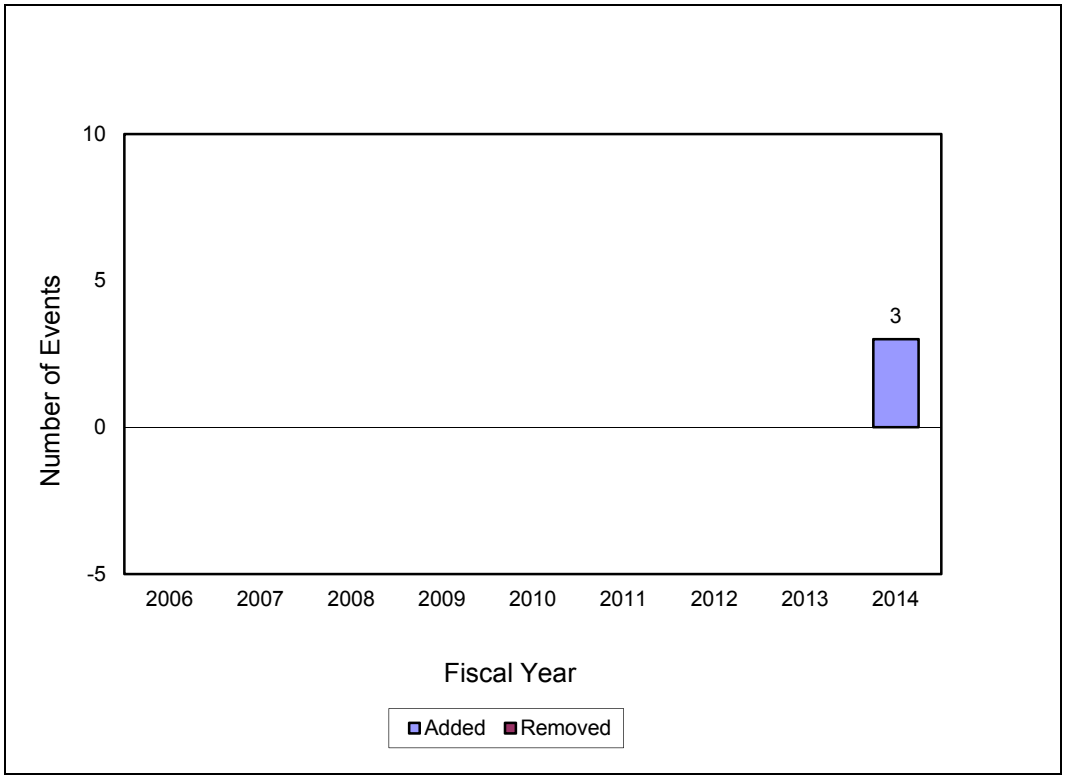

Figure D-9. Changes to FCP Data

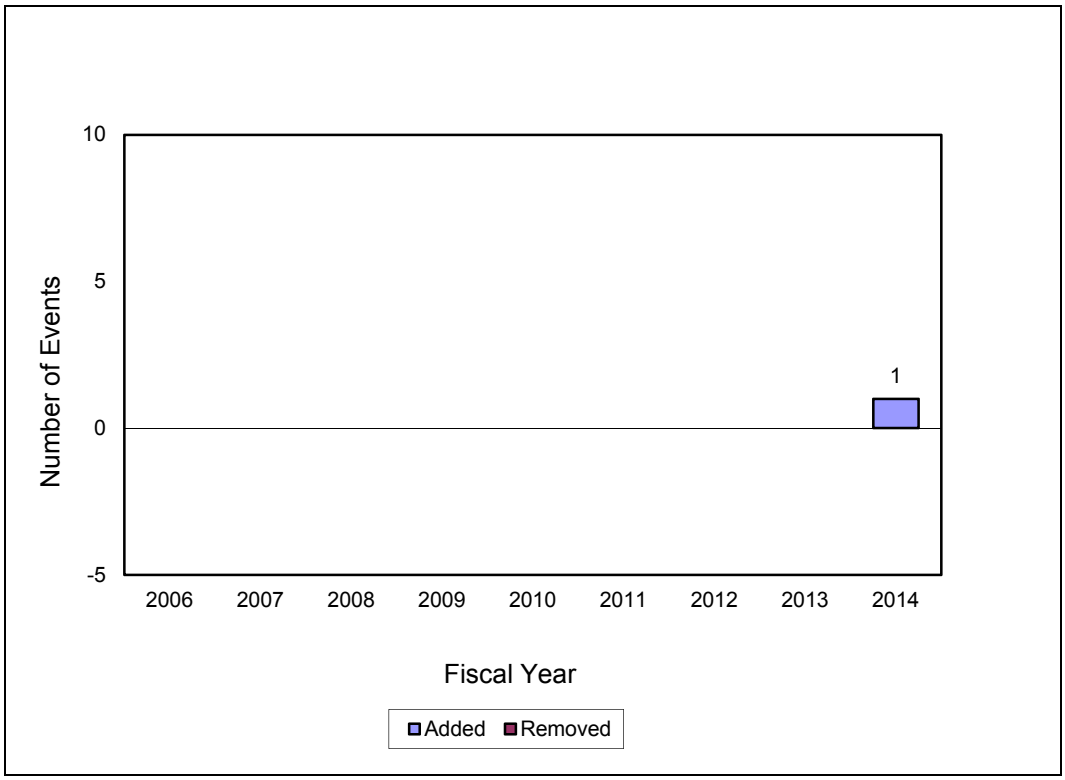

Figure D-10. Changes to OTH Data