ORNL/SPR-2019/1087

# NUCLEAR SMUGGLING DETECTION AND DETERRENCE

FY 2018

# DATA ANALYSIS ANNUAL REPORT

## A SUMMARY OF DATA RECEIVED AND ANALYZED BY ORNL

Isotope and Fuel Cycle Technology Division

# Nuclear Smuggling Detection and Deterrence FY 2018 Data Analysis Annual Report

## Performance from October 1, 2017, to September 30, 2018

February 2019

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# Contents



# Acronyms

| | |
|---|---|
| CAS | central alarm station |
| DART | Desktop Analysis and Reporting Tool |
| DFUT | Daily File Upload Tool |
| FY | fiscal year |
| LMP | local maintenance provider |
| MCAAW | Multi-Channel Analyzer Alignment Wizard |
| MCR | monthly country report |
| NORM | naturally occurring radioactive material |
| NSDD | Nuclear Smuggling Detection and Deterrence |
| ORNL | Oak Ridge National Laboratory |
| RAADAR | Radiation Alarm Adjudication Data Analysis Report |
| RIST | Radiation Inspection Systems Team |
| RPM | radiation portal monitor |
| RDS | radiation detection system |
| SOH | state of health |

# Acknowledgments


Chris Pope, Jeremy Patterson, and Michael Shannon were crucial to the production of this year's annual report. This would not have been possible without the long-term diligence of Scott Alcala, who among many other things manages the database and drafted most of the queries upon which this report is built.

The ORNL Radiation Inspection Systems Team wishes to extend a congratulatory 20th "Happy Birthday" wish to the NSDD Program and all its accomplishments in building partner country capability to deter, detect, and interdict the illicit transport of radiological and fissile material through strategic points of entry and exit at seaports, airports, and border crossings.

ORNL is indebted to the National Nuclear Security Administration's Office of Nuclear Smuggling Detection and Deterrence, for whom this work was performed.

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# EXECUTIVE SUMMARY

The National Nuclear Security Administration's Office of Nuclear Smuggling Detection and Deterrence (NSDD) has facilitated the installation of more than 3,728 radiation portal monitors (RPMs) at 660 sites in 63 countries. This collection of RPMs represents the world's largest network of radiation detectors and provides one element of the defense-in-depth approach that supports the Global Nuclear Detection Architecture. These systems support NSDD's mission to build partner country capability to deter, detect, and interdict the illicit transport of radiological and fissile material through strategic points of entry and exit at seaports, airports, and border crossings.

NSDD works collaboratively with partner countries and international organizations to optimize the operation of these RPMs. The large amount of data provided by NSDD partner countries (summarized in the banner to the right) highlights the close cooperation and partnerships NSDD has built with 63 countries around the world. Thirty-two of these countries shared at least some RPM-related data with NSDD in fiscal year (FY) 2018. This significant level of data sharing is a key element that distinguishes the NSDD office as unique among nuclear nonproliferation programs and initiatives: NSDD can provide specific, objective, data-driven decisions and support for sustaining the radiation detection systems it helped deploy. This data analysis report summarizes and aggregates the RPM data provided to the NSDD office for analysis and review in FY 2018.

The data can be used to describe RPM performance and characterize the wide diversity of NSDD deployment sites. For example, NSDD deploys detector systems across sites with natural background radiation levels that can vary by a factor of up to nine from site to site. Some RPM lanes have few occupancies, whereas others have up to approximately 8,000 occupancies per day, and the different types of cargo traveling through a site can result in site-wide alarm rates that range from near 0% at some sites to above 3% at others. Based on the data received, the global average uptime for NSDD RPMs was 97% for FY 2018. NSDD takes all these factors into account in making recommendations to partner countries on how to most effectively manage and maintain site operations. NSDD utilizes reports and other information products created by ORNL Radiation Inspection Systems Team (RIST) data analysts to efficiently allocate the resources needed to detect and ultimately interdict illicit nuclear and radiological material.

## FY 2018 Data Highlights

**32**
Countries

**54**
Vehicle Crossing Sites

**41**
Seaport Sites

**8**
Airport Sites

**7**
Rail Crossing Sites

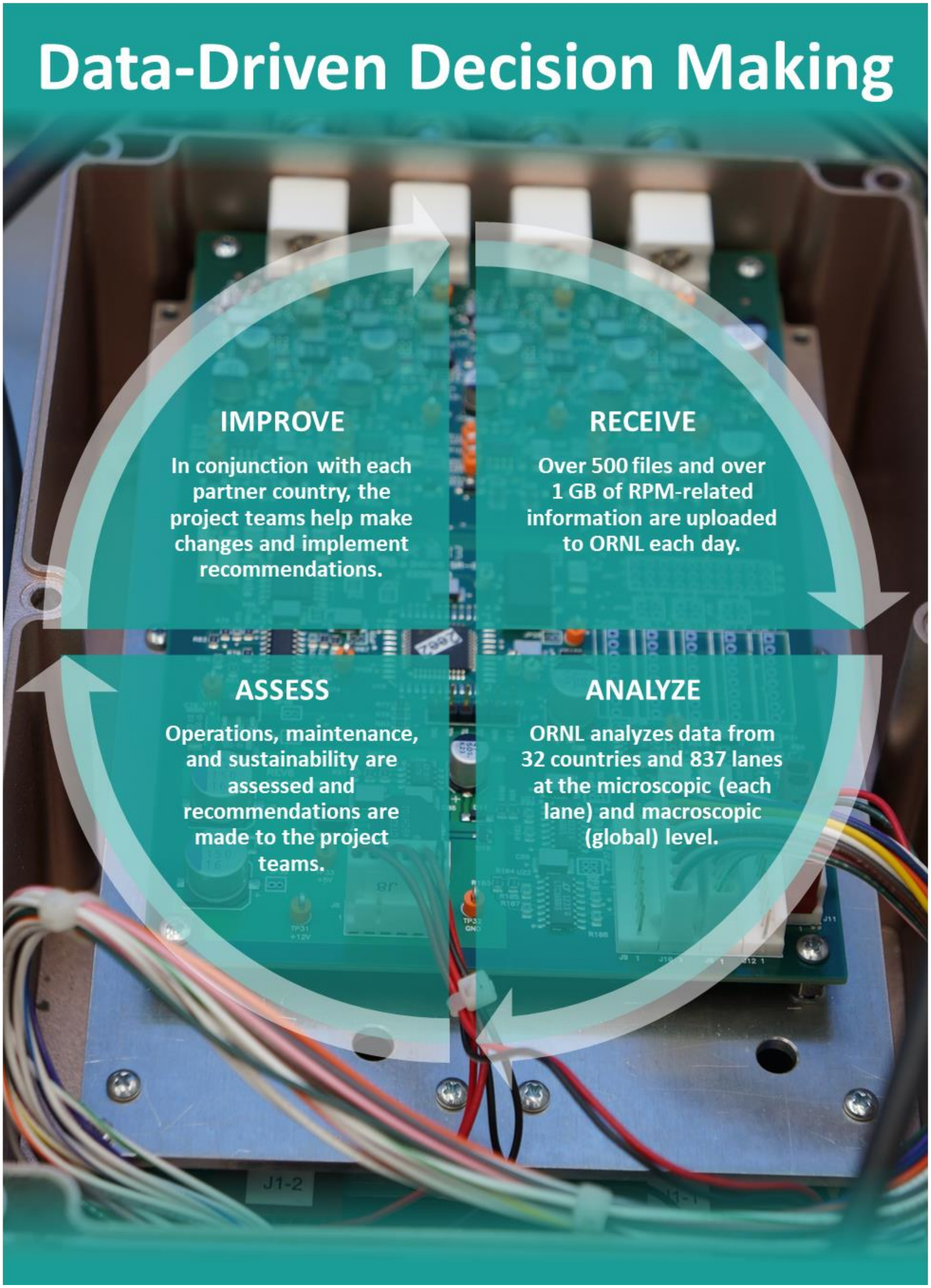
**837**
RPM Lanes

**0.87%**
Average RPM Alarm Rate

**70**
Million Occupancies

**187**
Thousand Files

**406 GB**
Data Received


Data-Driven Decision Making
IMPROVE
In conjunction with each partner country, the project teams help make changes and implement recommendations.
RECEIVE
Over 500 files and over 1 GB of RPM-related information are uploaded to ORNL each day.
ASSESS
Operations, maintenance, and sustainability are assessed and recommendations are made to the project teams.
ANALYZE
ORNL analyzes data from 32 countries and 837 lanes at the microscopic (each lane) and macroscopic (global) level.

# Introduction

The National Nuclear Security Administration's Office of Nuclear Smuggling Detection and Deterrence (NSDD) works with partner countries and international organizations to build a global capacity for the deterrence, detection, and interdiction of nuclear and other radioactive materials that are out of regulatory control. NSDD works with partner countries to assist in assuming the operational, maintenance, and management responsibilities for their radiation detection systems (RDSs), which include radiation portal monitors (RPMs). The Implementation program partners with the Sustainability program to promote continued operation and performance of the RDSs. These programs are implemented in conjunction with Los Alamos National Laboratory, Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory, and Sandia National Laboratories. Each of these national laboratories has a distinct mission related to NSDD. This report focuses on analysis of the collected data, which is ORNL's primary responsibility to NSDD.

ORNL is charged by NSDD with analyzing the data collected by the RPMs. Consistent, quantitative analysis of technical data generated by RPMs significantly contributes to maintaining performance and is important to the long-term operation and sustainability of NSDD systems. This work includes designing the tools and systems facilitating data collection, analyzing the data, creating reports that describe findings and trends about the operation of the RPMs, providing summaries of important issues to NSDD and its partner countries, and developing software to perform these functions. The benefits include

- identifying local operational deficiencies and equipment faults that partner country maintenance providers can remediate,
- optimizing detection efficiency and system responsiveness at the sites,
- identifying areas for improvement in equipment and operation,
- determining real-world requirements for future equipment,
- validating technical policies and assumptions, and
- determining RPM availability and other accountability metrics.

The findings presented in this report provide a concise summary that supplements these benefits and offer a practical perspective on trends in operational and equipment performance features across the Office of NSDD.

# RECEIVE: Data Sent to ORNL

NSDD has facilitated the installation of almost 3,730 RPMs in 63 countries. Site selection is based on a variety of factors, including the amount of traffic expected for scanning, the site's relative importance to suspected smuggling routes, and other geopolitical considerations. The relative ease of RPM installation and the potential for data sharing with the United States are also considered, though they are not requisite conditions for site selection.

The overwhelming majority of RPMs installed by NSDD are made by one of two manufacturers: ASPECT, a Russian company, and Rapiscan (formerly TSA Systems), a US-based company. ASPECT has provided approximately 54% of the RPMs deployed. NSDD, in cooperation with the Federal Customs Service of Russia, has implemented RPMs at all official entry and exit points to Russia, making it one of the largest consumers of RPMs. NSDD does not routinely receive data from ASPECT RPMs, even though they are capable of creating a daily file and being analyzed (see the Analyze section on page 5). In fiscal year (FY) 2018, NSDD did not receive any data from those sites where ASPECT RPMs have been installed.

Data for 837 of the US-made RPMs deployed worldwide were voluntarily shared with NSDD in fiscal year (FY) 2018 (Figure 1). This high level of voluntary data sharing attests to the utility and value of the data: the analysis results meaningfully improve operations and assist maintenance.

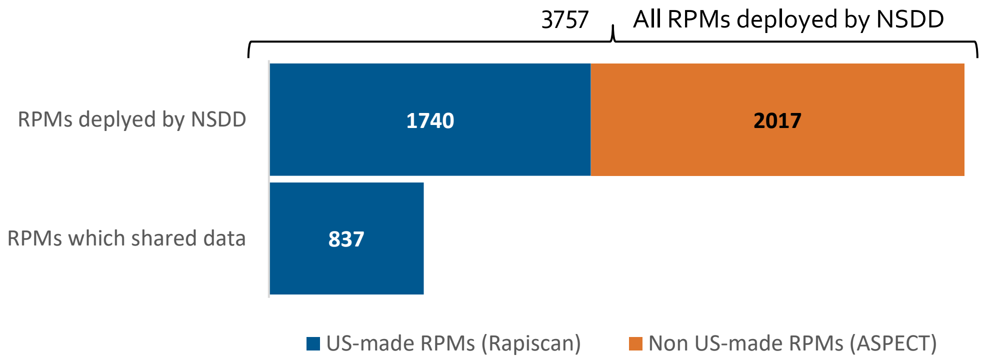



***Figure 1. In FY 2018, NSDD received data from about 45 percent of the US-made RPMs deployed globally.***

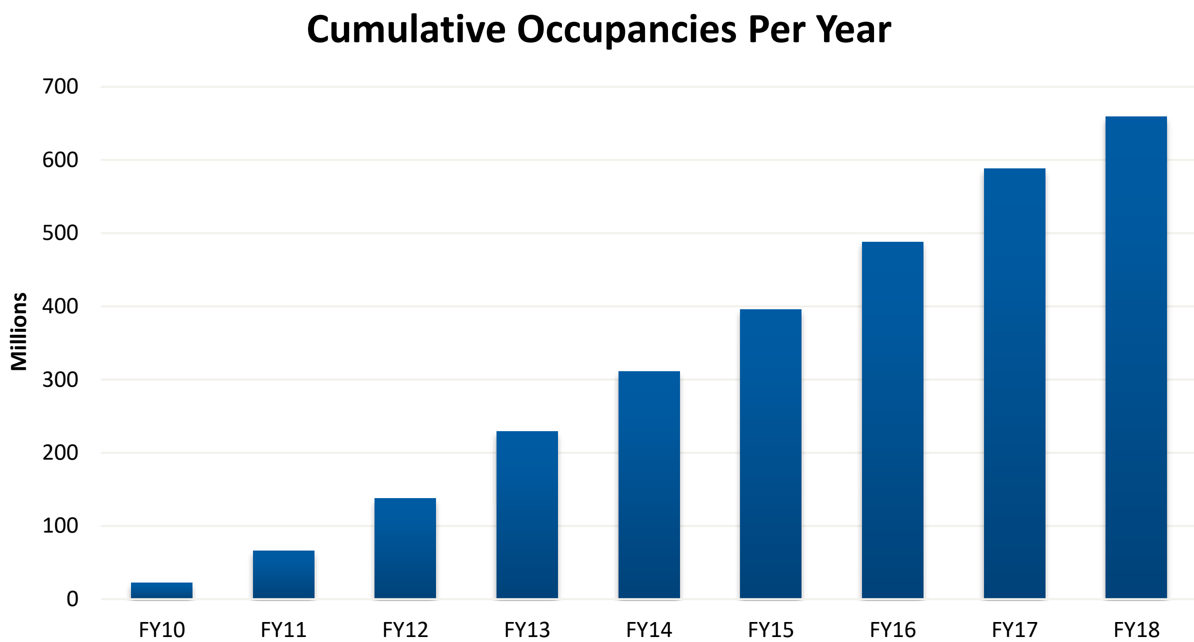



***Figure 2. FY 2018 occupancies were on par with previous years—roughly 70 million.***

Figure 2 shows that the number of occupancies in the data received was on par with the number of occupancies in the data received from previous years. NSDD has continued to receive data and occupancy information since FY 2010. Since 2008, when ORNL began rigorously storing the data, NSDD has received almost 660 million occupancies and 4 terabytes worth of data (explained further in the ANALYZE section). At least 70 million occupancies are analyzed each year to support this trend. This wealth of data gives an unparalleled baseline from which to draw inferences about the stream of commerce and the pace of operations at sites. For example, occupancy rates, alarm rates, and typical alarm profiles can be determined to help plan staffing and equipment needs. Country team efforts to transfer daily files to ORNL for analysis remain vigilant.

The United States does not own, operate, or in most cases, maintain the RDSs. By voluntarily sharing their data, the partner countries show both their commitment to the program (through the consistency with which they share data) and the value they receive from sharing the data (through the volume of information shared). NSDD works diligently to foster these relationships on many levels: technical, operational, and managerial.

RPMs scan a variety of traffic types, including vehicles, cargo trucks, trains, pedestrians, and luggage. Different types of RPMs are used depending on the application (Figure 3). Vehicle RPMs are the primary means of radiation detection for border crossings and seaports, and they are even deployed at a few airports. Pedestrian RPMs are most commonly found at airports to scan passengers and their luggage, but some are at border crossings to scan people as they walk from one country to another. Similarly, conveyor RPMs are most common at airports for scanning luggage. Last, rail RPMs—the largest RPMs deployed by NSDD—are used either at land border rail crossings or occasionally at seaports where site-specific requirements, such as wide lane spacing, dictate the need for larger and more sensitive RPMs.

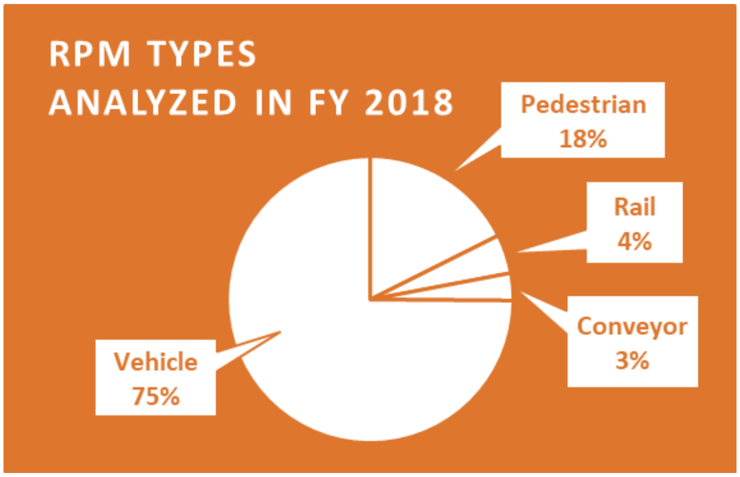



***Figure 3. ORNL analyzes data from a variety of different RPM types.***

NSDD received data from 837 RPMs in FY 2018. Figure 3 shows that most of the data analyzed by ORNL is from vehicle RPMs, which are widely deployed at both border crossings and seaports as the primary means of radiation detection. Data from pedestrian RPMs represent the second most commonly received RPM data, typically because of the large number of RPMs installed at airports.

Aside from the different types of RPMs, there are three primary site types from which NSDD receives data: airports, seaports, and vehicle crossings.

NSDD received data from 136 sites in FY 2018. The size of each bubble in Figure 4 is determined by the average number of occupancies each site records each day and the color of each bubble represents the site type. At airports (blue bubbles), pedestrians can stream through RPMs, quickly generating a large number of occupancies. Airports are also large installation sites for RPMs. It is not uncommon to have 20–30 pedestrian RPMs in a single airport, leading to thousands or tens of thousands of occupancies each day at a busy airport. Seaports (orange bubbles) and vehicle crossings (green bubbles), alternatively, vary widely in their daily occupancies. Therefore, Figure 4 shows the variation in traffic load of different site types within the NSDD program. What is acceptable throughput at some sites, perhaps even normal, is completely unacceptable at other sites because of the scale and size of the operation. NSDD takes these factors into consideration when establishing site-specific criteria for each RPM and operations.

Other site types not included in Figure 4 include rail crossings, training centers, ferry terminals, and mobile detection systems. The mobile detection systems enable local law enforcement agencies to scan traffic at a chokepoint along a roadway, or to drive next to stationary objects to perform real-time scans for radiological material, providing an advanced means of securing physical facilities such as crowded parking lots.

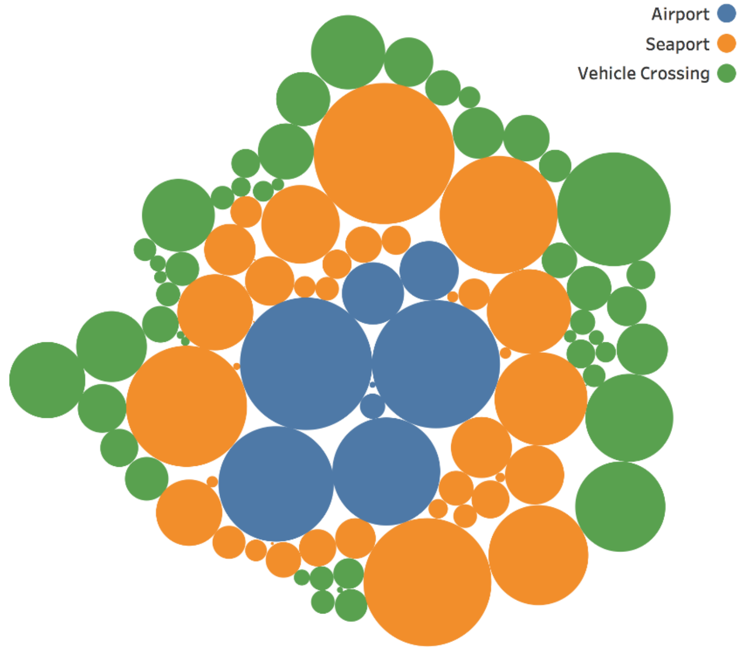



***Figure 4. ORNL receives data from a range of sites with widely varying throughput.***

# ANALYZE: Data Analyzed by ORNL

RPMs continuously collect information that is transferred to a central alarm station (CAS) at the site where the RPMs are installed. The data include alarms created by relatively high radiation levels in traffic going through the portals. These alarms indicate that additional inspection may be needed by local operators to determine if the object or person that caused the alarm poses a threat (e.g., the presence of unregulated or unlicensed nuclear / radiological material). Once a day, the CAS assembles the data collected by each RPM into a text file called a daily file (Figure 5). The data included in each file are RPM parameter settings, gamma and neutron radiation measurements taken when the RPM is both unoccupied and occupied, and faults and tamper indications. Partner countries that share data with NSDD provide these files to ORNL. Analysis of the data in these files is subsequently performed by experts at ORNL.

```
GB,000187,000197,000169,000186,09-37-03.661
NB,000003,000003,000003,000003,09-37-08.584
GB,000190,000194,000171,000187,09-37-08.661
NS,000003,000003,000001,000002,09-37-13.624
GS,000035,000044,000026,000033,09-37-13.628
GS,000037,000041,000036,000039,09-37-13.649
GS,000032,000039,000044,000039,09-37-13.652
GS,000044,000039,000023,000038,09-37-13.657
GS,000035,000035,000036,000035,09-37-13.659
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GS,000036,000033,000037,000042,09-37-13.781
GS,000027,000038,000024,000032,09-37-14.045
```

***Figure 5. Sample contents of an RPM daily file.***

Each partner country can have multiple sites where equipment is deployed, and each site typically has multiple lanes equipped with RPMs. Consequently, a lane is the unit used to count RPM deployments and to organize daily file data for analysis.

## Site Traffic

The NSDD office deploys RPMs to a highly diverse set of locations, ranging from major seaports to remote border crossings. This section more closely examines the sites from which NSDD receives data and discusses how the conditions for radiation detection vary from one site to the next. This information can be helpful in characterizing sites, both existing and planned, against the full spectrum of NSDD sites.

Figure 6 shows the average number of occupancies per lane and the average alarm rate per occupancy, categorized by fiscal year for airports, seaports, and vehicle crossings. In FY 2018 pedestrian RPMs located at airports again saw the lowest, on average, alarm rates while experiencing one of the highest average occupancy rates, whereas RPMs located at seaports continued to see the highest alarm rates. In general, seaports tend to see higher gamma alarm rates because of the significant quantity of bulk commodities shipped, including ceramic tile, some types of fertilizer, and many abrasives. Bulk commodities such as these contain naturally occurring radioactive material (NORM) in large enough concentrations to generate alarms at the RPMs.

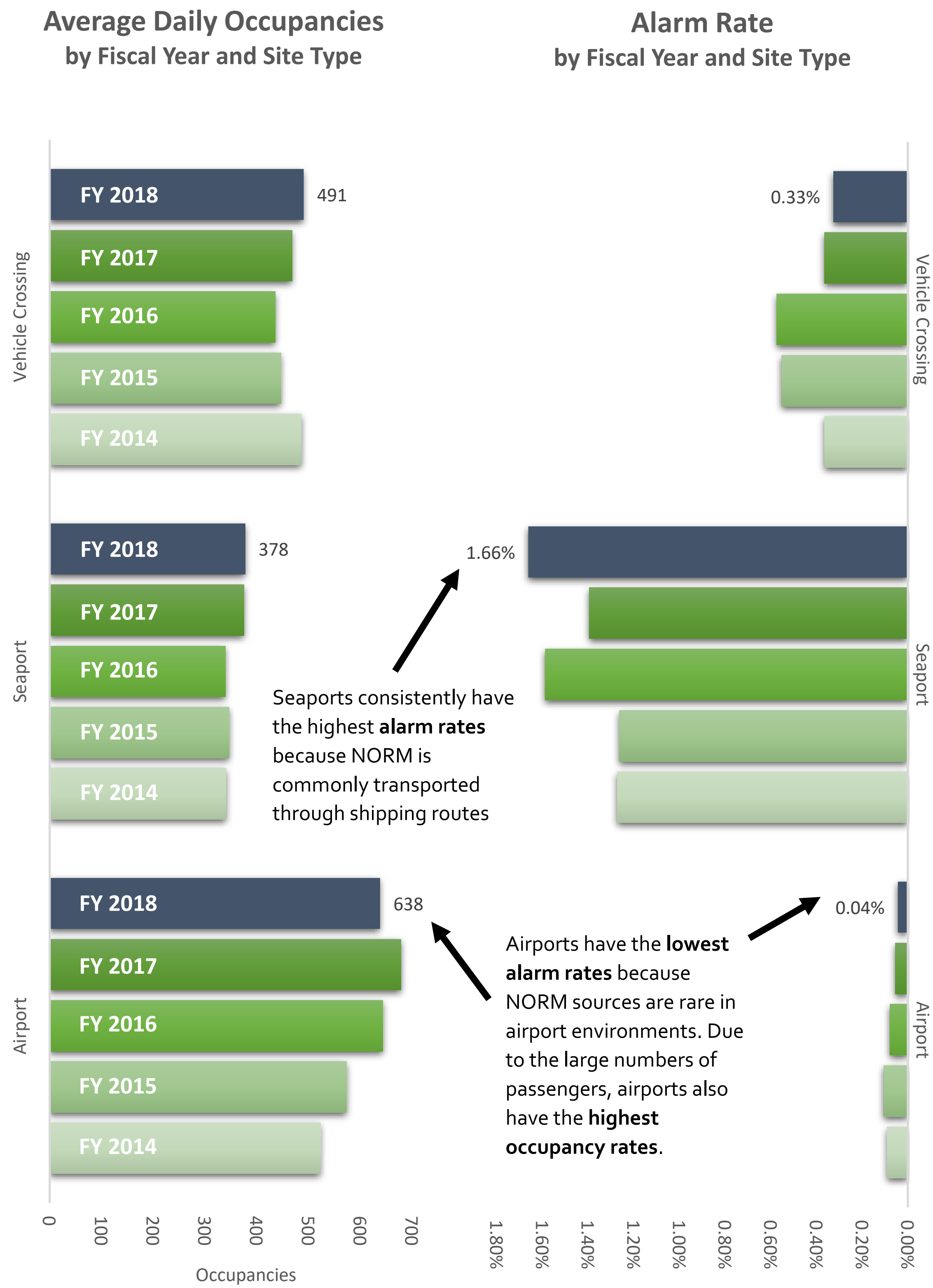



***Figure 6. The average occupancies and alarm rates differ by site type.***

Airports see lower alarm rates because of the lower amounts of NORM transported through them. Pedestrians typically do not carry enough NORM-containing material to generate an alarm. However, some medical diagnostic and treatment techniques include radioactive substances, which are easily detected by RPMs. In these cases, a single patient can cause multiple alarms as a result of the RPM's sensitivity. Other sources of alarms include nearby X-ray machines (very common for scanning luggage at an airport), radioactive check sources during RPM maintenance, or malfunctioning detector equipment.

The Office of NSDD uses this wide range of traffic volume information to work with partner countries to ensure that sufficient resources and training are available for adjudicating alarms and refining secondary inspection procedures.

NSDD tracks gamma and neutron alarm rates, shown in total over the last 5 years for airports, vehicle crossings, and seaports in Figure 7. The rate of neutron alarms tends to be much lower than the rate of gamma alarms because there are fewer neutron-emitting sources moving through these sites than gamma-emitting sources, which are most commonly identified as NORM.

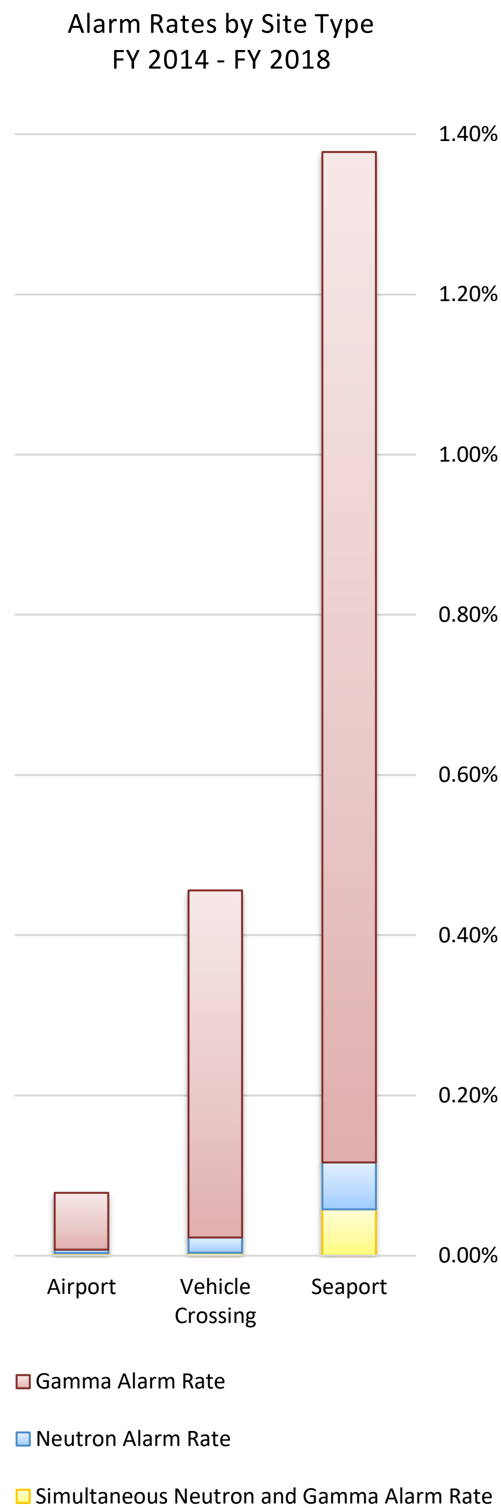



***Figure 7. Gamma alarms are the most common type of alarm for all deployment locations.***

## Site Background Radiation

Understanding the background radiation level at a site is necessary to determine the smallest amount of radioactive material that can be reliably detected at that site. The higher the background level, the harder it can be to detect a weak radioactive source—like hearing a whisper in a noisy room. Other elements, like vehicle speed and RPM settings, must be considered when determining the overall minimum detectable quantity of radioactive material.

The background level is dependent on the surrounding environment. A location at a high altitude, where the thinner atmosphere allows more cosmic radiation to penetrate, or a location featuring a large amount of exposed granite, which may contain uranium and thorium, will typically have a higher background level than a location at sea level or with sedimentary rock in the vicinity. In addition, the inclusion of NORM in roadway concrete near an RPM can contribute to the measured background. In some cases, collimating the RPMs or repaving the road with concrete containing less NORM can help reduce the background measured by the RPMs.

Figure 8 shows a histogram of the gamma background count rates for detectors at seaports and vehicle crossings averaged over each site that provided data in FY 2018, and it shows that the gamma background can vary widely from site to site. The site with the highest average background is nine times higher than the site with the lowest average background.

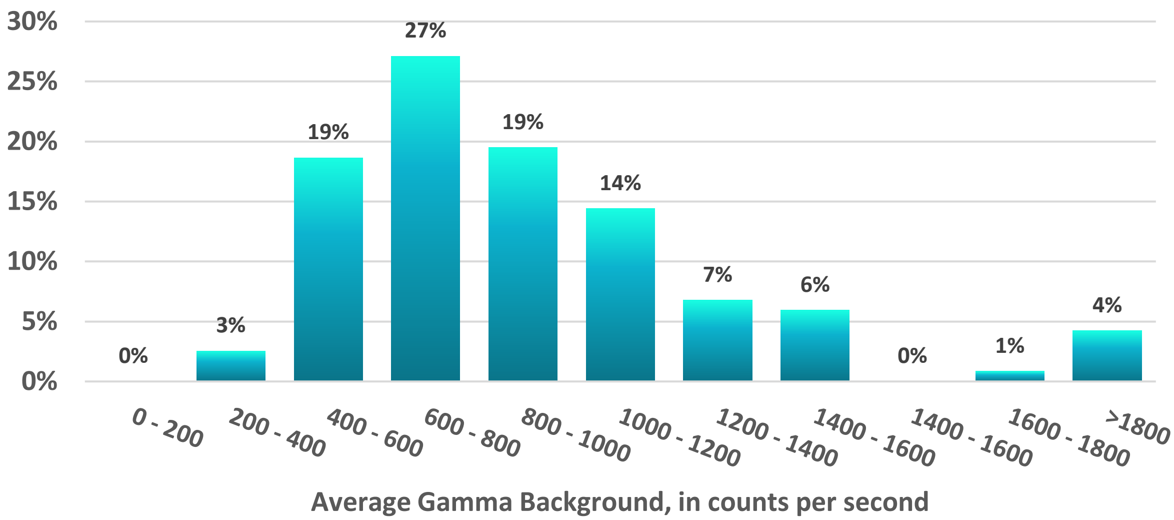



***Figure 8. Gamma background count rates tracked at NSDD seaports and vehicle crossing sites in FY 2018. Lower backgrounds enhance RPM sensitivity.***

Figure 8 shows that most RPMs are deployed to relatively low background environments, in which the RPMs have greater sensitivity. In high background locations, NSDD will sometimes engage in background remediation, such as paving over or removing sections of ground that are most strongly affecting the background. Regardless, part of NSDD's acceptance and turnover process specifically includes setting the parameters of each RPM to the specific conditions of its environment.

## Lane-Specific Alarm Information

The Office of NSDD monitors and tracks the alarm rates observed at individual lanes, and although site- and country-level summaries are useful for managing and planning resources, handling operations and responding to alarms occur at the lane level. Each lane is equipped with an RPM and frequently with cameras and other equipment required by the site. The combination of RPMs, cameras, network equipment, secondary inspection equipment, and the CAS comprises the RDS at a site. Figure 9 provides a breakdown of the gamma alarm rates by lane for all RPMs. Over 75% of the lanes show an alarm rate of 1% or less, whereas 85% of lanes show an alarm rate of 2% or less. The alarm rate each site can manage is highly dependent on available resources, as well as the number of occupancies each lane receives each day. For instance, a 5% alarm rate is manageable if only 60 vehicles travel through the lane each day, resulting in three alarms per day. A 5% alarm rate can be more difficult to appropriately respond to if 1,000 vehicles travel the lane each day, resulting in 50 alarms per day. Separate analysis routines can calculate the backlog of alarming vehicles at each site, and NSDD works with partner countries to determine the best path forward to managing alarm rates.

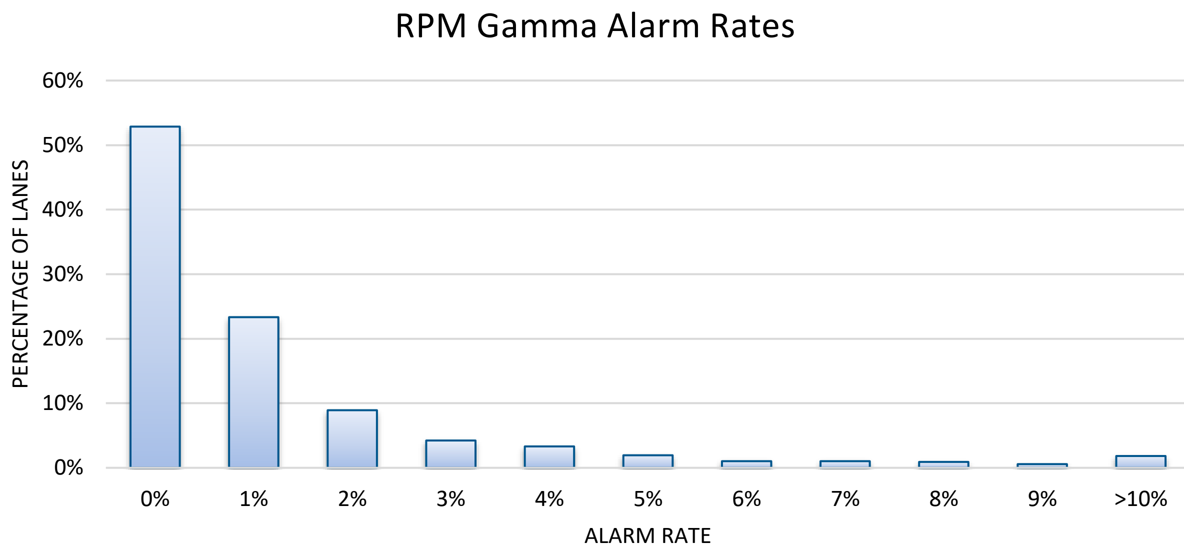



***Figure 9. Gamma alarm rates for RPM lanes are generally low, with some exceptions.***

## Gamma Alarms for Secondary Inspections

Gamma alarms can be generated from a variety of sources, ranging from benign NORM sources to lost industrial sources or nuclear material. Unfortunately, the strength of the gamma signal is not connected to its severity. For instance, a patient who has recently received a medical radiopharmaceutical treatment can give off orders of magnitude more gamma radiation than some threat sources. When an RPM generates an alarm, a separate piece of equipment (usually a handheld radioactive isotope identifier) is used to resolve the alarm, regardless of whether the source of the alarm is weak or strong. Plots like those in Figure 10 are critical for determining the performance requirements for secondary systems.

The two red circles in Figure 10 highlight two sample points on the orange line. The lower left circle is at the 50% cumulative total of all alarming occupancies; it indicates that half of all alarms generate about 500 counts above background ("net counts") or less. The upper right circle is at the 95% cumulative level; about 95% of all alarms generate 3,400 net counts or less at the RPM. In other words, about 1 in 20 alarms (5%) generates more than 3,400 counts per second, as recorded by NSDD RPMs. Data points like these can inform requirements for secondary inspection systems and next-generation energy discriminating systems answering such questions as "How 'hot' is the typical NORM source?" and "Can the secondary inspection system still discern threat material inside of a cargo load of NORM?"

Other features in Figure 10 are discernable. The bumps in the area chart (teal) represent common NORM commodities: each bump represents a type of material that emits about the same amount of gamma radiation. For example, potassium-based salt, used for road salt or water softeners, emits about the same amount of radiation regardless of where in the world it is mined. Another feature is the sharp spike on the right side of the area chart. This upper 1% of alarms represents the highest gamma radiation readings, and they are most commonly due to testing with sources (for instance, during calibration or a maintenance procedure) or a patient who has recently received a radiopharmaceutical treatment.

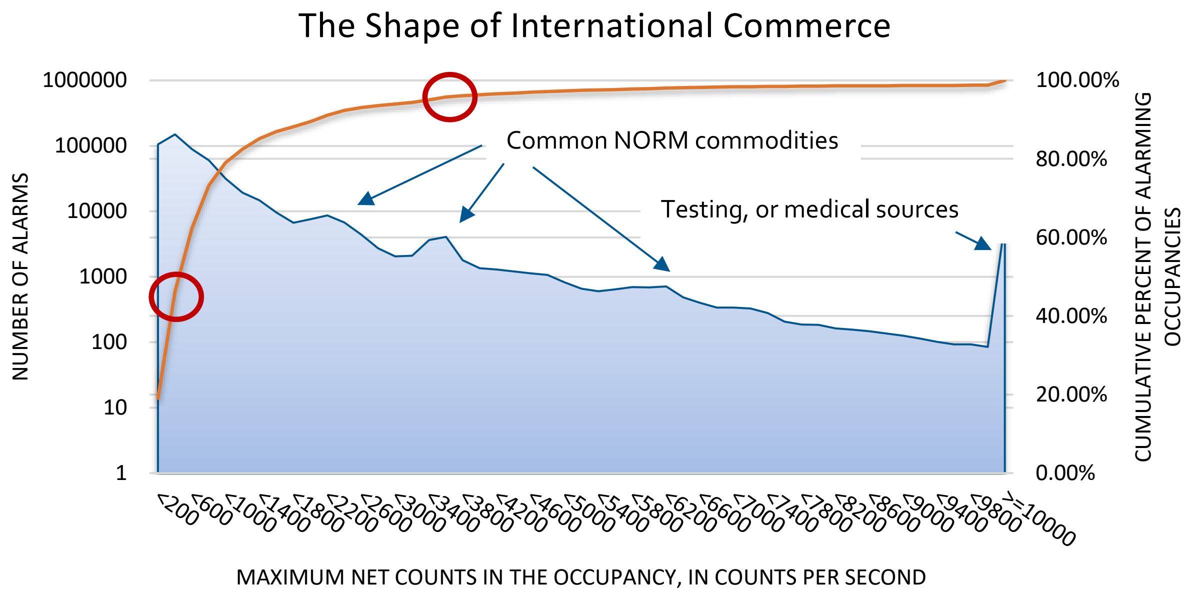



***Figure 10. Distribution of net gamma counts for all alarming occupancies from vehicle RPMs in FY 2018.***

# ASSESS: Data Analysis Products

Data analysis supports the sustainability of NSDD detection systems by informing project teams of systematic issues at the site, country, or program level. For this purpose, several reports are produced.

## Monthly Country Reports

The primary report used by NSDD is the monthly country report (MCR), which is produced every month for each country that submitted data. ORNL generated over 231 MCRs in FY 2018. These reports summarize operational elements for each RPM: number of occupancies, number of gamma and neutron alarms, and number of faults. Analysis of data over a long period (e.g., 1 month) can provide valuable, objective answers to the following questions:

- Is the equipment operating as intended?
- Is the equipment being properly maintained to support its operations?

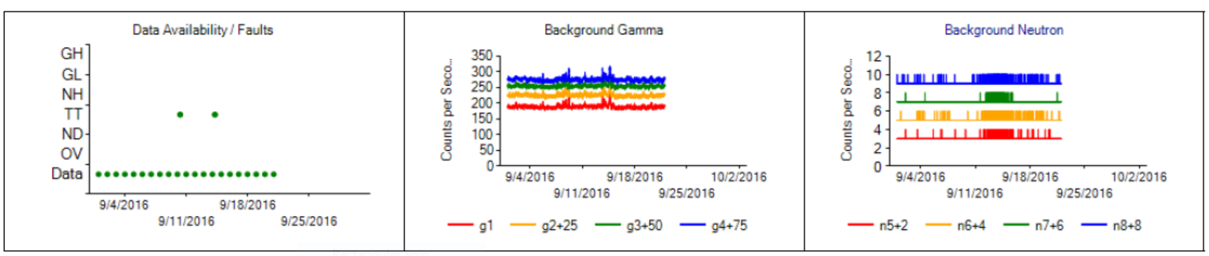
ORNL's RIST data analysts review the data from each RPM each month and provide their findings in the MCR (Figure 11). Long-term analysis like this can identify failing components and other problems before they become an operational burden.

Monthly Country Report
Cricket_September 2016
9/1/2016-9/30/2016

**Triple - Lane 001 (Vehicle)**

Data only available through 9/21.
Both neutron alarms on 9/21 at 10:55am and look like testing.

| Data Availability | | Occup Metrics | | Bkgrd G.Metrics | | Bkgrd N.Metrics | | Fault Metrics | |
|---|---|---|---|---|---|---|---|---|---|
| First (in rpt month): | 9/1/2016 | Occup Count: | 14763 | Tot Avg Bg: | 795.5 | Tot Avg Bg: | 7 | Gamma High: | 0 |
| Last (in rpt month): | 9/21/2016 | Occ / Day: | 703 | Avg Bg 1: | 189.3 | Avg Bg 5: | 1.7 | Gamma Low: | 0 |
| Total Files: | 21 | G.Alarm Count | 1 | SDev Bg 1: | 5.9 | SDev Bg 5: | 0.6 | Neutron High: | 0 |
| Oversize Files: | 0 | G.Alarm Pct: | 0.007 | Avg Bg 2: | 200.7 | Avg Bg 6: | 1.8 | Tamper Open: | 2 |
| Empty Files: | 0 | G.Alarm / Day: | 0.048 | SDev Bg 2: | 6 | SDev Bg 6: | 0.6 | Tamper Close: | 2 |
| Bad Format Files: | 0 | N.Alarm Count: | 2 | Avg Bg 3: | 205.1 | Avg Bg 7: | 1.7 | | |
| Missing Files: | 9 | N.Alarm Pct: | 0.014 | SDev Bg 3: | 5.7 | SDev Bg 7: | 0.6 | | |
| | | N.Alarm / Day: | 0.095 | Avg Bg 4: | 200.4 | Avg Bg 8: | 1.8 | | |
| | | Speed (Mode): | 13 | SDev Bg 4: | 6.2 | SDev Bg 8: | 0.6 | | |




**Gamma Settings**

| Timestamp | Backgrd High Fault | Backgrd Low Fault | Intervals | Occupancy Hold-In | N.Sigma | Detectors On-Line | Master L.Level Discrim | Master U.Level Discrim | Relay Output | Algorithm | Slave L.Level Discrim | Slave U.Level Discrim | Backgrd Time | Backgrd N.Sigma | Firmware Version |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/21/2016 12:51 AM | 630 | 100 | 5 | 10 | 11.400 | 1111 | 0.069 | 0.455 | 1 | 1010 | 0.069 | 0.455 | 20 | 0.000 | 1.10.1 |

**Neutron Settings**

| Timestamp | High N.Fault Alarm | Max Intervals | Alpha Value | zMax Value | Sequence Number | nBkgrd Average Time | Master L.Level Discrim | Master U.Level Discrim | Slave L.Level Discrim | Slave U.Level Discrim |
|---|---|---|---|---|---|---|---|---|---|---|
| 9/21/2016 12:51 AM | 50 | 3 | 4 | 1200 | 1 | 120 | 0.504 | 5.040 | 0.504 | 5.040 |

***Figure 11. A fictitious MCR that shows status information for one RPM for 1 month. Items that need attention (missing data, neutron alarms, tamper indications) are highlighted in yellow.***

## Lane State of Health

The lane State of Health (SOH) is a key element of the MCR, as it allows site operators, project teams, and foreign partners to assess the health of a lane quickly and easily based on a comparison of the lane with appropriate criteria. As shown in Figure 12, the report highlights lanes as red (immediate attention required), yellow (items to address at the next convenient opportunity), or green (no issues with lane operation).

| Light | Files% | Empty% | Oversize | Speed | gAlign | nAlign | gVar | nVar | gSet | nSet | Faults | Tampers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Green | 10 | 0 | 0 | -1 | 0.928 | 0.950 | 0.781 | 0.979 | 0 | 0 | 0 | 0 |
| Yellow | 10 | 0 | 0 | 0 | 0.978 | 0.956 | 0.916 | 0.969 | 0 | 0 | 0 | 0 |
| Green | 10 | 0 | 0 | 843 | 0.941 | 0.984 | 0.874 | 0.965 | 0 | 0 | 0 | 0 |
| Yellow | 10 | 0 | 0 | -1 | 0.945 | 0.931 | 0.906 | 0.720 | 1 | 0 | 1 | 0 |
| Yellow | 10 | 0 | 0 | -1 | 0.922 | 0.926 | 0.884 | 0.939 | 1 | 0 | 0 | 0 |
| Green* | 10 | 0 | 0 | 0 | 0.887 | 1.000 | 0.822 | 1.000 | 0 | 0 | 0 | 0 |
| Green | 10 | 0 | 0 | 549 | 0.897 | 0.979 | 0.898 | 0.941 | 0 | 0 | 0 | 0 |
| Green | 10 | 0 | 0 | -1 | 0.000 | 0.000 | 0.000 | 0.000 | 0 | 0 | 0 | 0 |

***Figure 12. Lane State of Health charts allow quick assessment of individual RPM status. Each row is an RPM, and each column is a different evaluation metric.***

## Country Manager's Report and Sustainability Manager's Report

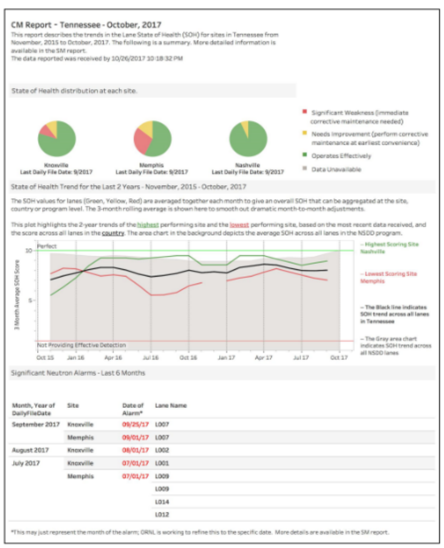



***Figure 13. The Country Manager's Report provides a 1-page summary of RPM performance each quarter.***

One challenge is to distill the tens of gigabytes of technical data received each month into easily understandable and actionable reports. To achieve that, all RPM information is condensed into a single-page Country Manager's Report once per quarter, as shown in Figure 13. This single-page report shows the location of each RPM and the SOH of each RPM over the past quarter. Trend graphs showing the best-performing and worst-performing sites over the last year are also provided. The Country Manager's Report allows an at-a-glance view of the RPMs for a given country and indicates which sites may be most in need of attention. By referencing other, more detailed reports, decision makers can make informed decisions on whether additional training or other forms of assistance are needed.

At a greater level of detail, Sustainability Manager's Reports are produced on a monthly basis. These reports provide a depiction, in graphical form, of the country's RPMs that most frequently alarm or cause faults. The ranking of RPMs allows project team members to objectively quantify which RPMs are most in need of attention. Like the Country Manager's Report, it enables an objective assessment of how operations, training, and maintenance are being performed relative to the RPMs. Whereas the single-page Country Manager's Report may identify that something is wrong, the Sustainability Manager's Report can identify what is wrong and why.

## Quarterly Availability Report

ORNL tracks the overall uptime of RPMs from the available data and publishes the results in a quarterly availability report. A small portion of the availability report is shown in Figure 14. The uptime of all RPMs within a country is calculated and shown in a box-and-whiskers plot. Statistical outliers can be identified (such as the pink star in Figure 14), and ORNL works with project teams to identify and correct long-standing issues. The report also highlights the previous quarter's poor performers and the improvement seen this quarter, which provides a nice synopsis of NSDD's dedication to maintaining and sustaining RPMs.

The overall uptime for all RPMs in FY 2018 was 97%.

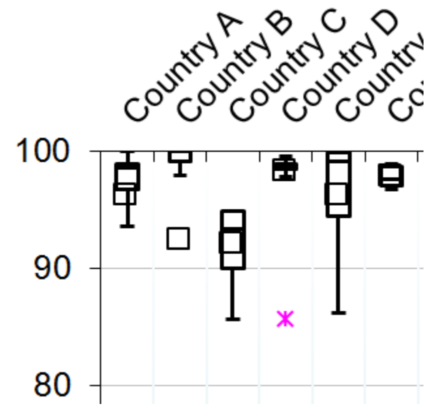



***Figure 14. Example box-and-whisker plot showing RPM availability for each country.***

## Software Tools: DART and MCAAW

***Figure 15. Maintenance providers use MCAAW software to align RPM gamma detectors.***

As part of its mission to analyze RPM data for NSDD, ORNL develops and distributes software tools to partner countries to enable them to perform the same analysis as ORNL. In-person and over-the-internet training is available to all partner countries to assist them in taking on these responsibilities.

The first of these is the Desktop Analysis and Report Tool (DART), which allows maintenance providers to analyze daily file data while on-site to provide additional information about any work they are about to perform. It is also the tool ORNL data analysts use to generate the MCRs (Figure 11). DART is useful for, among other things, identifying faulty or failing components and operational issues affecting RPM sensitivity and analyzing secondary inspection wait times.

Another software tool is the Multi-Channel Analyzer Alignment Wizard (MCAAW). MCAAW leads technicians through the process of aligning (or calibrating) an RPM (Figure 15), and it automatically records all the necessary information for proper documentation and verification. Data files can be sent to ORNL for confirmation as well. Monitoring and trending of calibration data over months and years can be crucial to identifying long-term trends and behaviors.

NSDD provides web-based training at no cost to the partner country to any user who wants additional instruction in using these tools.

## Daily File Upload Tool

Because daily files are an integral piece of the NSDD data analysis mission at ORNL, it is important that uploading daily files is as simple and seamless as possible. To assist in this regard, the Daily File Upload Tool (DFUT) was created by Sandia National Laboratories in collaboration with ORNL to automatically submit the latest daily files from an NSDD site to ORNL once installed on the CAS. The DFUT runs an automatic nightly upload of daily files to the ORNL-managed NSDD Upload site. As of FY 2018, the DFUT has been successfully implemented in five countries and this number will hopefully increase in FY 2019.

Figure 16 shows the time delay between the date that files were generated at their respective sites and when they were uploaded to ORNL. Each color represents a different fiscal year, with the blue color representing FY 2018. An inflection point is seen at 30 days, indicating that ORNL typically receives daily files from sites monthly or quarterly, depending on the partner country and site. However, since the DFUT's first installation in FY 2017, a large spike can be seen in the distribution in the range of 1–3 days. These are the files automatically uploaded to ORNL by the DFUT. In addition to streamlining the local maintenance provider's (LMP's) job by eliminating the need to manually upload daily files, the DFUT allows ORNL to analyze the data and notify project teams of RDS maintenance and operations problems in a timely manner. This has provided a consistent, unbroken stream of data for trend analysis.

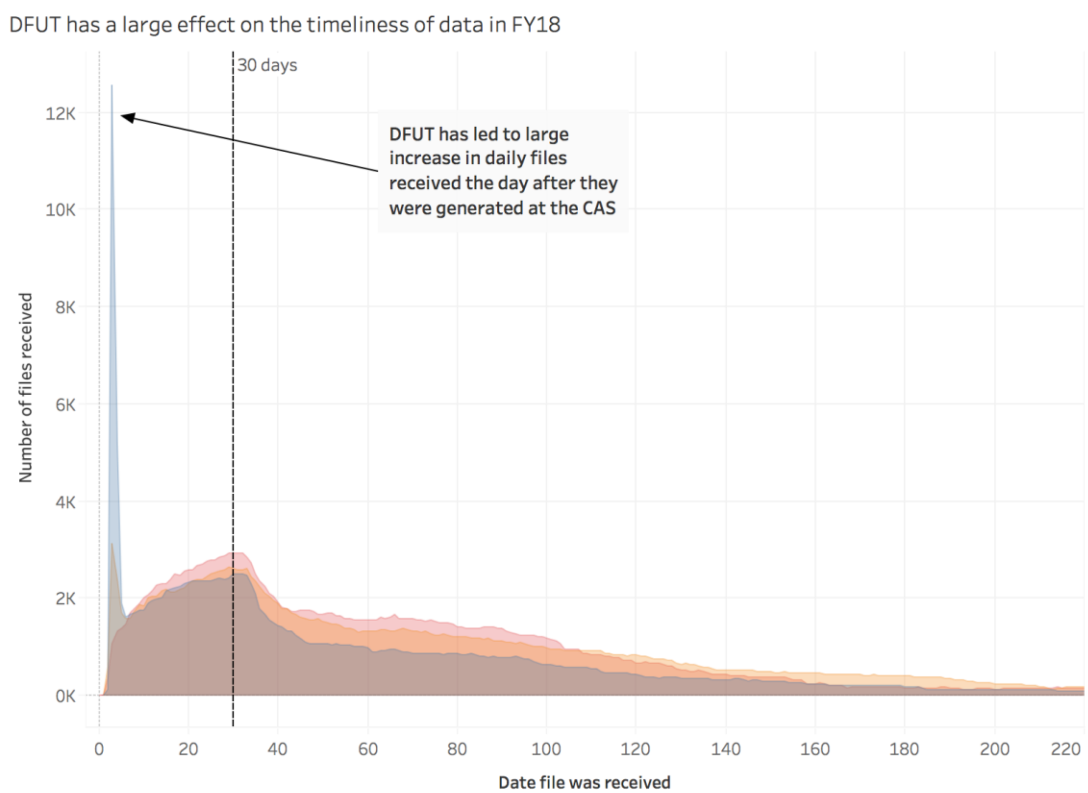



***Figure 16. The difference between the date of a daily file's generation in the CAS and arrival at ORNL. The Daily File Upload Tool automatically uploads daily files every night, leading to a spike in the distribution at 1 to 3 days.***

# IMPROVE: Feedback and Reporting

The Office of NSDD's data analysis efforts are part of a continuous improvement process for installed RDSs. Systems are installed in dynamic environments where operational changes, physical changes, or changes in the traffic being processed may indicate that the system is no longer ideally suited to the circumstances of the site. Therefore, a key element of NSDD's continuous improvement process is to take actions to adjust systems to new circumstances and to continually monitor data to understand the effects of those actions. NSDD fosters an environment of close collaboration to ensure that data analysis recommendations are understood and considered by project teams. NSDD project teams then take a variety of actions to improve the reliability and effectiveness of installed systems based on the recommendations of the data analysis team. These improvement recommendations generally fall in three categories: physical, operational, and settings adjustments.

## Physical Improvements

Physical improvements are changes to the physical configuration of an RDS to improve its reliability or effectiveness. Because recommendations for physical improvements generally involve the deployment of equipment, project teams implement these recommendations by integrating them into the budget planning process, and recommendations are deployed using standard project management practices.

One example is when an X-ray machine is installed near an existing RDS. The use of X-ray systems makes this a common occurrence at airports, where baggage scanners may create an issue, and at some seaports, where large systems may be used to scan cargo containers. X-rays are identified by an RPM as gamma radiation, resulting in false alarms. The short-duration pulses from X-ray systems have a characteristic signature that can be identified by the NSDD data analysis team, who may recommend to the project team that X-ray shielding be installed. Figure 17 depicts a typical site layout in which an RPM is exposed to X-ray interference, and Figure 18 gives sample RPM data and alarm rates for an RPM before and after the installation of X-ray shielding. Shielding also affects the normal background radiation detected by the RPM, which analysts must consider when determining new setting values. Data analysts monitor RPM data and report their findings to the project team after shielding has been installed to ensure the X-ray interference has been eliminated.

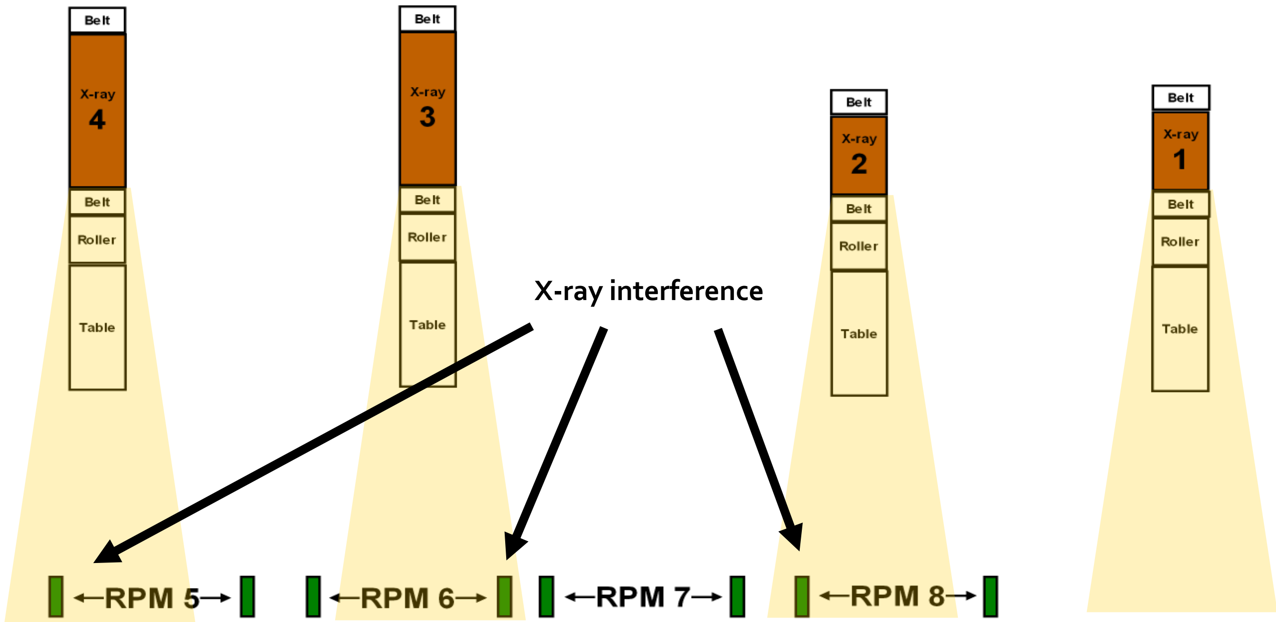
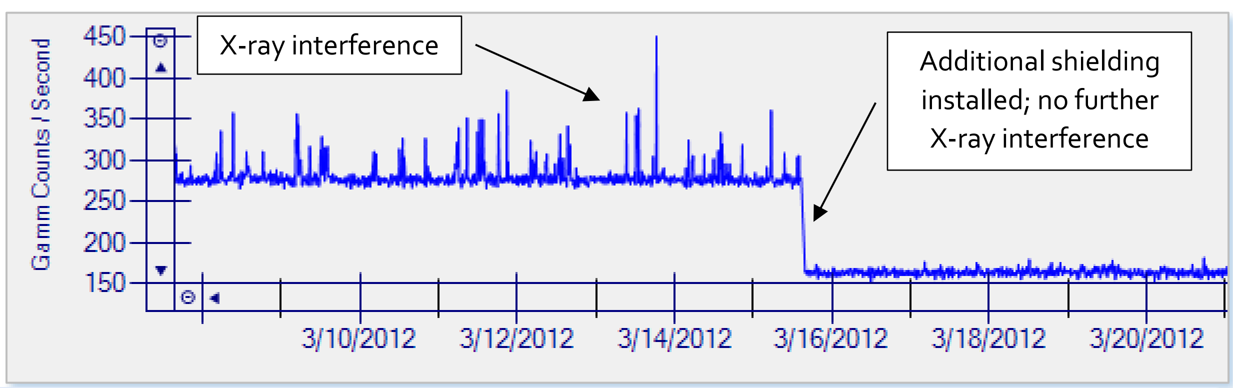



*Figure 17. Diagram of typical X-ray interference.*




| | January | February | March | April | May |
|---|---|---|---|---|---|
| **Alarm Rate:** (Alarms/day) | 6.0 | 5.9 | 2.6 | 0.2 | 0.3 |

Significant decrease after
X-ray shielding was installed

*Figure 18. Example RPM data before and after X-ray shield installation.*

Over the years, NSDD's data analysis efforts have supported physical solutions like the one just described to decrease false gamma and neutron alarm rates and to improve RDS reliability and sensitivity.

## Operational Improvements

NSDD strives to install RDSs that minimize operational impact to the site. However, not all issues detected through data analysis can be remediated by physical changes to the system. In some cases, adjustments to site operations are the most efficient way to improve RDS effectiveness. These adjustments may include changes to management practices, training, or procedures associated with RDS operation to improve its reliability or effectiveness.

One operational problem is known as "crowding," which occurs when people or vehicles crowd close to an RPM without occupying it (Figure 19), unintentionally shielding the RPM from natural background radiation in a way that makes false alarms more likely.

***Figure 19. Pedestrians crowding a pedestrian RPM, which can lead to false alarms.***

ORNL's RIST data analysts can detect the crowding signature in RPM data and will recommend that project teams work with the appropriate partner country authorities to mitigate it. Typically, this involves working with local managers and operators to alert them to the issue and to identify changes to site operations that preclude unnecessary crowding. After operational changes are made, ORNL data analysts continue to monitor RPM data to ensure the issue has been resolved.

NSDD takes a whole-system approach to data analysis and has recently begun to derive operational insights by combining RPM data analysis with analysis of CAS alarm adjudications (Radiation Alarm Adjudication Data Analysis & Reporting, or RAADAR). This combination allows for a more in-depth analysis of RPM alarms and can provide ground truth for some issues that cannot be resolved through RPM data alone.

In FY 2018, such analysis at one site revealed that some excess "extended occupancy" faults and false alarms that were known through RPM data analysis could be eliminated through changes to setting values at the CAS and the RPM. RPM data alone had been insufficient to determine the appropriate settings change. Analysis of RPM data in conjunction with CAS alarm adjudication data enabled a change that has significantly alleviated an operational issue at this site.

The RAADAR analysis further showed that operators were marking some commodities as NORM more often than would be expected (Figure 20). This led to both operational and training adjustments, and preliminary data indicate that improvements have been made to increase the site's effectiveness at remaining vigilant against smuggling of nuclear and radioactive materials.

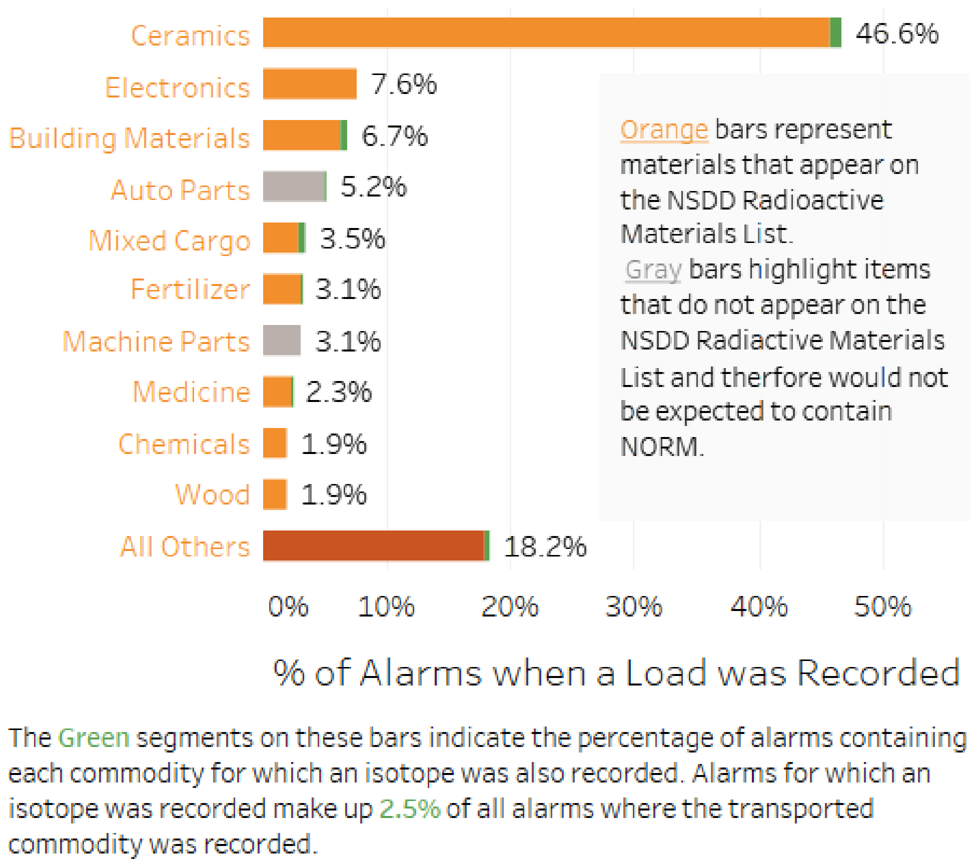



***Figure 20. NORM commodities identified by operators responding to RPM alarms. Some identified commodities would not be expected to contain NORM.***

## Continuous Improvement

Data analysis is part of NSDD's continuous improvement process for deployed RDS installations. After making changes to the physical, operational, or settings configuration of an RDS, RPM data are continually monitored to ensure the changes were effective. The effectiveness of these interventions is also verified through a project team's direct interactions with partner country stakeholders during assurance visits or through feedback received from LMPs. Together, these efforts ensure NSDD maximizes the efficiency and effectiveness of RDS deployments long after their initial installation.

# Conclusions

With 70 million occupancies recorded in FY 2018 alone, the year proved to be another successful one for NSDD:

- NSDD now has a global record of almost 660 million occupancies, allowing informed decisions to be made in a global context.
- NSDD received data from 837 RPMs in FY 2018, providing a deep knowledge base upon which to selectively focus resources.
- RPM availability, or uptime, for FY 2018 was 97%, showing that the RPMs deployed by NSDD are generally being sustained and maintained by partner countries.
- Through objective measures and system-based analysis provided by ORNL's Radiation Inspection Systems Team (RIST) data analysts, development and deployment of innovated software solutions, and longer-term relationships fostered with partner countries, NSDD can direct resources appropriately to maintain capabilities at their intended levels.

NSDD is uniquely positioned among nonproliferation programs to make data-driven recommendations about how to best optimize RPM operations and, ultimately, to positively influence the ability of sites to deter, detect, and interdict illicit nuclear and radiological materials. Information such as this report—as well as additional site-specific information in conjunction with site visits and other assessment techniques—provides the Office of NSDD with valuable resources to support partner countries in strengthening their capability to prevent the illicit trafficking of nuclear and other radioactive materials. This report is just one of many tools used by NSDD to maintain the consistency, proficiency, and effectiveness of installed equipment.