

Using Cloud Virtual Machines to Strengthen Interactive Virtual Training

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ABSTRACT

The National Nuclear Security Administration's Office of Nuclear Smuggling Detection and Deterrence (NSDD) plays a critical role in the U.S. nonproliferation mission by providing training to partner countries on radiation detection systems used to detect, disrupt, and investigate illicit trafficking of nuclear and other radioactive material out of regulatory control.

Over the past decade, training provided by NSDD has evolved as part of an effort to be responsive to the needs and capabilities of partner countries. Initially, NSDD instructors provided in-country training to central alarm station (CAS) system administrators, operators, and maintenance providers using PowerPoint and printed course materials. In 2016, NSDD began using virtual machines (VMs) hosted on systems brought to the location by instructors. While the VMs were a significant improvement to the traditional PowerPoint materials, there were increased costs associated with maintenance, sanitizing, and reimaging the VMs after each training event. Anticipating the need to continue evolving, NSDD pursued an opportunity to invest in the use of cloud-based technology to identify more advanced training delivery options.

The investment in cloud-based technology allowed NSDD to be at the forefront of training continuity for performance-based activities, which could not have been timelier. The COVID-19 pandemic and subsequent travel restrictions created the need for NSDD to quickly adapt training courses for virtual delivery in order to continue providing effective, capacity-building training for partner countries, regardless of the instructor's proximity to the trainees.

NSDD VMs are deployed in a cloud-based environment and accessed remotely by trainees. The VMs are configured with vendor-specific CAS software and networking that allows trainees to remotely engage in live, instructor-led training that closely simulates in-person instruction. This hands-on approach provides job-related familiarization through a fully interactive, no-fault setting that allows trainees to safely learn the radiation detection systems they will be accessing in their duties as system administrators, operators, and maintenance providers.

Providing NSDD partner countries uninterrupted training during a pandemic demonstrates the agility of the NSDD training platform. This unique strategic approach closely imitates on-site instruction at a significantly reduced cost to the NSDD Program by decreasing U.S. instructor travel and associated labor costs.

INTRODUCTION

Conducting partner country engagements such as training are important components of capacity building within Nuclear Smuggling Detection and Deterrence (NSDD). System Administration (Sys Admin) training includes systems-based concepts and practical application in central alarm station (CAS) system interfaces. The training has traditionally depended on use of PowerPoint lectures with limited access to a live system on-site. It is common for there to be one CAS per site, which means training tasks are dependent on system availability resulting in limited access since the priority is daily operations. Given these conditions, in 2016 NSDD evaluated alternative approaches for conducting the Sys Admin training. An evolution occurred that moved training from being delivered in-country, on-site with limited access to CAS systems; to in-country, on-site with virtual machines (VMs), to remotely with cloud VMs – prior to the travel bans that began during the COVID-19 pandemic in 2020.

Sys Admin Training Description and Target Audience

NSDD offers System Administration curriculum, which includes training modules for two different radiation detection systems: Schneider Electric and Rapiscan Radiation Alarm and Video Event Notification (RAVEN). These training courses provide an understanding of the CAS system software and hardware along with the tools and resources to perform systems administration functions. The training is designed for system operators who perform basic maintenance and computer administrative tasks as well as maintenance providers with practical information technology (IT) skills, who perform complex, expert-level routine and corrective maintenance functions.

MDS OT Training Description and Target Audience

NSDD offers a Mobile Detection System (MDS) Operator Training course designed to provide an understanding of how to detect and interdict radiological or special nuclear material outside of regulatory control. The MDS uses the RAVEN CAS and is targeted for new or inexperienced equipment operators and their immediate supervisors. It is designed to cover a wide user group including Border Police, Border Guards, Customs Officers, National Police, and nuclear response agencies.

Improving Instructor-led Training Through the Use of VMs

The initial purpose for updating the CAS training was to consistently deliver operator and system administrator training while increasing hands-on activities. Additionally, it was important to create a no-fault environment because it is essential trainees have opportunities to make mistakes without penalty during the learning process. When using a live system during the Sys Admin training was the only option, trainees displayed a hesitancy to fully engage in activities, and some tasks were not performed, for fear of breaking the system without being able to repair it in time to resume normal operations.



Figure 1. NSDD VM solution for in-classroom CAS operator and system administration training.

Given the need to improve access to systems for skill development, NSDD decided to use VMs as a solution for activity-based training with partner countries. According to Wikipedia, “a VM is the virtualization or emulation of a computer system. VMs are based on computer architectures and provide functionality of a physical computer. Their implementations may involve specialized hardware, software, or a combination.” Essentially, an alternative to using the live on-site CAS was created by running CAS system applications on the hardware based VMs. This configuration was packaged into NSDD “VM kits” that instructors would hand-carry to in-country training events. Each kit included an instructor laptop, a laptop server that hosted the CAS system VMs, a wireless router, and twelve (12) Surface Pros that the trainees used to connect to a specific VM. This solution did not require internet access and instead used a local area network (LAN) that provided connectivity from the host, through the wireless router to the instructor laptop and Surface Pros.

The laptop server is configured to run using VMware’s Hypervisor platform ESXi. The ESXi Hypervisor provides one of the most efficient ways to run VMs due to the limited overhead and use of system resources. The ESXi operating system is installed on Secure Digital (SD) cards and the SD card slot is configured as the boot drive. A separate SD card is configured for each CAS so when the server powers on, only the VMs for the selected CAS start. The instructor inserts the selected SD card prior to powering on. The instructor laptop is used to verify the VMs are operating, observe trainee use, and demonstrate CAS operations to the trainees with a projector.

The simulator VM operates the radiation portal monitor (RPM) and camera simulator software that is used by the instructors. The simulator software provides RPM and camera data to the trainee VMs. Trainees are provided a Surface Pro that connects them to their assigned VM using virtual console client software. Trainees then can login and navigate through the different features of the CAS software. This configuration allows the reproduction of event alarms and faults by the instructor in a manner emulating real world scenarios. Trainees can acknowledge the events and adjudicate them. When shutdown, each trainee VM reverts to a snapshot, discarding changes created throughout the day’s training by returning the VM to its original state, ensuring an operational CAS the next time the VM is started.

The response from partner countries using the VMs during the CAS training was incredible and the intended outcome was achieved. Trainees demonstrated increased engagement and were able to ask more informed questions due to their direct participation in activity-based tasks, compared with prior offerings that were PowerPoint dependent. While the trainees benefited, there was a logistical complication that occurred from administering the VMs. Instructors had to lug heavy, cumbersome equipment around the globe to teach using this new tool.

The use of VMs for international nuclear security training events is a relatively new approach for NSDD and one that has become viable as access to more affordable and dependable technology has become available globally. The use of VMs proved it was possible to develop and deploy interactive training using a realistic, simulated environment. The next step was to figure out how to reduce the physical strain on instructors during travel and focus on improving the cost related to developing and maintaining this new training aid.

Comparison of Hardware versus Cloud VMs

VMs were used for engaging in-person training but had a set of limitations that inspired investigation into the feasibility of cloud VMs. A review of benefits and challenges of each configuration was done to determine whether NSDD building the cloud VMs for a pilot program would be beneficial.

The virtual disks used in the VM kit were converted to a format compatible with Microsoft's Azure Cloud platform and uploaded to the Azure NSDD Cloud Training storage. Using the Azure Portal (Figure 2), each VM is then recreated using the virtual disk and connected using a virtual network. This allows the VMs to operate in the same manner as the VM kit. A public internet protocol (IP) address and a Domain Name System name is assigned to each VM when it is started. The network is configured to limit access to only an allowed list of IP addresses to enable trainees and instructors the ability to connect using Remote Desktop Protocol clients.

Challenges were encountered with the RAVEN CAS, which uses a unique computer called a concentrator. The operating system (OS) used by the concentrator did not have drivers needed to operate in the Azure cloud. This was mitigated by running Oracle's Virtual Box software on the RAVEN VM and hosting the concentrator as a "nested" VM. Each RAVEN VM runs the RPM and camera simulator software independently and is controlled remotely by the instructor using a web browser. These run in the background as services, so they are not apparent to the trainee.

Snapshots are taken of each virtual disk after updates and configuration changes. Prior to each training, the trainee VMs are recreated from the snapshot to ensure a clean system free from changes that may have been performed by a previous user. Only the required number of trainee VMs and the instructor/simulator VM for the desired CAS are started prior to training.

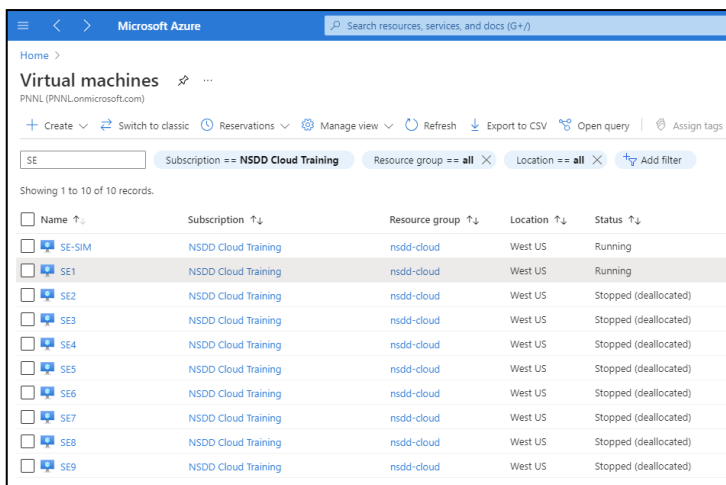


Figure 2. View of NSDD Cloud VM Management via Azure Portal

A comparison showed the VMs and cloud VMs offer the same functionality but have stark differences. A hardware based VM kit is carried in-country by the instructor and weighs 50 lb. The VM kits included multiple devices that used a LAN for connectivity. The number of trainees was dependent on the number of Surface Pros physically available in the kit.

In contrast, the cloud VM is accessed via the internet, therefore it is not reliant on a physical location for training purposes. The number of instances run is practically limitless, with trainees logging in from their work or personal computers to access a web-based option. The simulated CAS is in a cloud-based environment that can be accessed remotely via an internet connection and does not require purchasing additional hardware or software (Figure 3). There is not a limit on the number of people that may participate due to technology, although enrollment may be capped due to available bandwidth and training recommendations.

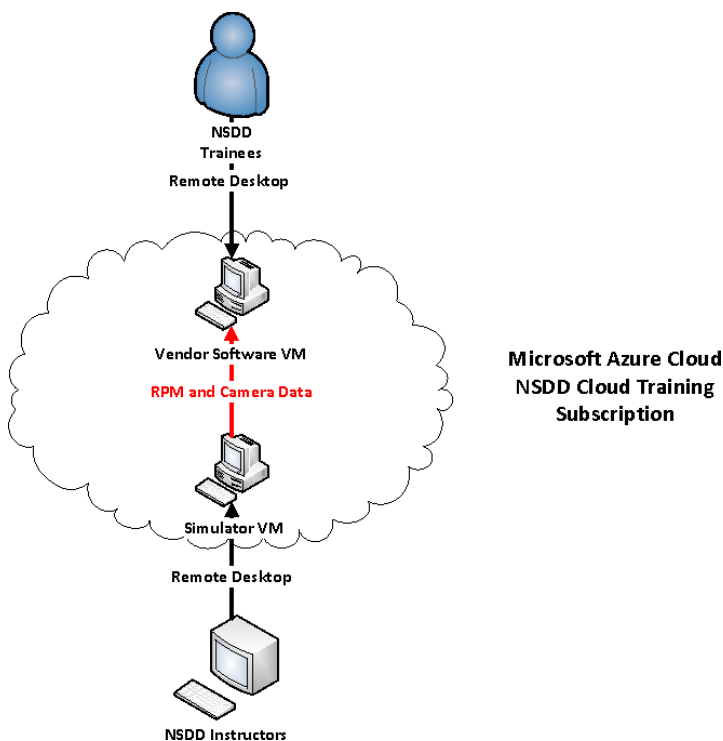


Figure 3. Trainee and Instructor access to the Cloud VMs

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The VM kits, first developed in 2016, have been deployed eight times to eight different countries and were even used to support internal lab training for instructor qualifications. Funding for the cloud VMs was approved in January 2020 and they were being setup as travel restrictions began in March 2020. The development of cloud VMs prior to the COVID-19 pandemic provided an opportune training aid that allowed continued engagement with partner countries despite travel restrictions.

Ideally, the cloud VMs will be the primary choice for future trainings, however, the VM kits have not been retired. The kits may still be used in areas where there is no internet connection or poor connectivity where use of the cloud VMs would be unreliable.

Using Cloud VMs to Conduct Engaging Remote Training

Video conferencing platforms such as Zoom, or MS Teams enable U.S. instructors to connect with trainees domestically or internationally. Using cloud VMs during remote training requires coordination between NSDD and the partner country but has become a model for productive, highly interactive sessions. The Sys Admin curriculum is designed for trainees to actively participate in instructor-led activities that leverage the real-time environment in the CAS VMs, giving them hands-on experiences. Use of a simulated RPM environment allows trainees to safely learn the systems they will be accessing in their duties as System Administrators and Operators when they complete the training.

Eliminating the physical VMs has a few benefits. First, there's nothing to carry! What a relief for instructors who manage connecting flights and the responsibility of hand carrying the heavy kits. There is also less pressure to update and maintain the equipment that goes into the kits and the potential damage that can happen each time they were sent into the field. Ultimately, the cost of managing the kits is eliminated, along with any stress associated with their journey.

Budget constraints have encouraged exploration of alternative training delivery options. In implementing cloud VMs for use during remote delivery, not only has the management of physical inventory been eliminated but travel expenses, U.S. instructor requirements related to international travel (for example, visas or vaccines), and travel risks have also disappeared. This is appealing for a variety of technical curriculum that may also be well-suited to hands-on activities via a cloud VM. Modern video conferencing platforms are more widely available to partners and allow the effective training to occur without lengthy travel. Consider the cost savings from decreasing or eliminating U.S. instructor travel and associated labor costs. At the time of the NSDD proposals, it was estimated that preliminary savings are in the range of \$10-20K per traveler, per event.

The flexibility benefits both U.S. instructors and international partners who can connect without the additional expense of being at the same physical site. U.S. instructors have been able to use both cloud VMs and video conferencing applications to conduct interactive training regardless of their geographical location. Additionally, partner countries may invite trainees from sites around the country to attend instructor-led training at a central facility. The cost incurred from the travel expenses, as well as the required equipment and printed materials to support in-person events, has been reduced, if not eliminated for our partners.

This new approach to training was proposed, and development was under way, prior to the pandemic. Amazingly, the availability of remote training delivery synced up with the travel restrictions and seamlessly allowed training to successfully continue. Once normal travel resumes, this new method of remote training delivery method will persist as a viable option.

Planning training can now be dependent on the partner country's need and availability. The cloud VMs do not have a set number of trainees but rather may be limited by bandwidth. This is a dramatic change from the original Sys Admin offerings that used the live, on-site CAS restricted trainees to 12, with training primarily occurring in a classroom. Even the use of the VM kits limited

the number of trainees to 12 but increased interactions with one Surface Pro per trainee. Now, the cloud VMs may offer an unlimited number of enrollments, however, due to instructional best practice, 12 trainees is the recommended maximum number.

Challenges and Solutions

Continued implementation of remote Sys Admin training using the cloud VMs presents some challenges each time it is offered. Many times, this is due to the unique conditions of our partners. Common issues that may be mitigated include limited bandwidth, issues with IP addresses, adequate equipment on-site, and cloud VM preparation. The Azure cloud has many regional locations around the world where the VMs could be deployed to improve bandwidth.

Reliable internet access and available bandwidth vary greatly in different countries. This has been an issue for countries where there were other large meetings occurring at the same time and same location. In-country technicians must be available to assist and remedy. The troubleshooting process can be time consuming and may impact trainee access to cloud VMs if not resolved promptly. Testing and evaluation needs to be conducted for each training location. In addition, a test run at the designated venue using the same equipment that will be used for the actual event should be conducted prior to broader implementation. It may also be a good idea for the sustainability manager to check with the site to determine if other events requiring internet are scheduled for the same time. In some instances, weather may even cause connection issues so an awareness of this on a country-to-country basis may be useful. Ultimately, instructor flexibility is key in offering options to conduct the training.

Another issue that has been seen is trainee IP addresses changing from what was originally provided by the partner country. Trainees send the IP address of the computer they will connect from in-country, this provides access permission to a VM. Issues have occurred occasionally but has been resolved during the pre-course connectivity check. Instructors are prepared to update with the latest IP addresses and confirm cloud permissions prior to the start of training each day.

If the trainees are in one location, such as a training room, specific hardware is required: a computer to connect to video conferencing application such as Zoom or MS Teams. The same computer must be connected (HDMI) to display device (monitor, tv) for trainees to view the virtual classroom. Additionally, a microphone(s) and speakers are required. If trainees are co-located on-site, then a sound bar is useful as it incorporates audio/video capabilities in the shared space. Trainee laptops for connection to VMs are required. If adequate equipment is unavailable, coordination to purchase in-country in advance of the training event at NSDD's expense is possible. NSDD may also be able to ship hardware but to date this has not been necessary.

Sufficient cloud VMs are provisioned prior to the training. An event simulator is incorporated on each VM. The instructor can connect to each VM simulator from the instructor VM and generate events for specific VMs. The conversion from VMs to cloud VMs enabled the continuation of interactive, hands-on training via remote delivery. This approach accomplished the original intent to increase skill development during in-person, instructor-led training but has also proved to

significantly increase engagement during remote training as well. Offering the Sys Admin training throughout the pandemic has been proven successful in large part due to the availability of the cloud VMs.

Next Steps

Due to the success of the cloud VMs in the NSDD curriculum, the program is considering additional skill-based courses that may benefit from it. Demonstrations of the cloud VMs have also been presented to the capacity building functional team within International Nuclear Security (INS), another program office under Global Materials Security (GMS). Awareness events were conducted to share what is possible and generate new ideas about how cloud VMs can be used to increase engagement during capacity-building events. Other government agencies who support international training may consider the applicability of cloud VMs to their training programs given the demonstrated success and receptiveness of NSDD partner countries.

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