Development and Deployment of Physical Protection Systems for Mobile Radiological Sources Used in the Well Logging and Industrial Radiography Industries

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ABSTRACT

The threat of dirty bombs or radiological dispersal devices (RDDs) is real, and the U.S. Department of Energy/National Nuclear Security Administration's (DOE/NNSA) Office of Global Material Security (GMS) has spent over a decade understanding the threat and working to protect vulnerable high-activity radiological materials across the globe that are used in everyday medical, research, and industrial applications. Radioactive sources are used in radiography to inspect welds or metal integrity, and in the oil and gas industry to characterize exploration and production wells to provide critical data to exploit geological formations in pursuit of oil caches. These mobile radioactive sources are of sufficient curie quantities to be categorized as desirable sources for terrorist organizations. Over the last ten years the Pacific Northwest National Laboratory (PNNL) has been leading an effort for GMS to work with industry partners and mobile radiological device manufacturers to develop technology that can be integrated into the daily operations of these industries and provide an enhanced level of security both domestically and internationally.

The fundamental security challenge of mobile radiological devices is the control and accountability of the source when it is in transit or in use in the field. Maintaining control and accountability of the location of the source and confirming that the source is in fact still in the proper container is critical when addressing this specific security concern. Working with industry, PNNL developed a Mobile Source Transit Security (MSTS) system that monitors, records, and reports the status of mobile radioactive sources using sensor based, active technology to track the source shields/cameras, calibration sources and verifiers. The MSTS system is designed to be integrated into the industries' standard equipment and vehicles and contains an internal radiation detector that can detect the presence of the individual source. Alarms are sent to the base of operations center to immediately notify key personnel in case the source is lost or illicitly removed.

This paper will discuss the progress to-date on the design, development, and deployment of the MSTS system, and outreach to the international community. More specifically, lessons learned from early field deployments, technology transfer strategies, and initial international deployments will be discussed.

INTRODUCTION

The U.S. Department of Energy/National Nuclear Security Administration's (DOE/NNSA) Office of Global Material Security (GMS) supports global efforts to combat nuclear and radiological terrorism. Within GMS, the mission of the Office of Radiological Security (ORS) is to reduce, remove, and protect vulnerable radioactive sources and, in so doing, deny potential terrorist access to radiological materials. Many of these vulnerable sources are contained in heavy and static self-shielded devices such as blood irradiators, radiotherapy machines, and industrial irradiators. However, there is a significant amount of radiological material used in industry that is mobile in nature that the ORS program has sought to protect.

These sources are in use globally and present several challenges for physical security when compared to their more stationary counterparts. The ORS Program's focus has been on domestic deployments while new technology for mobile source security has been refined with the help of its industry partners. While there has been some outreach with global stakeholders for radiological security, deployments have been limited to a few key international partners through the ORS Program's partnership with industry. These initial deployments have presented several opportunities for lessons learned which will be detailed in this paper. These lessons are invaluable as the ORS Program continues its work to mature this technology and provide a launching pad for it to be more widely accepted by mobile source users in their day-to-day operations.

INDUSTRY BACKGROUND

Industrial Radiography and Well Logging are major tools in the Oil and Gas industry, among others, to perform non-destructive testing (NDT) and to perform assay of well characteristics. Both use radioactive sources, and both are mobile in nature. Industrial Radiography Source Projectors use Iridium-192 in a hand-carriable configuration for ease of transport and for in-field operations while well logging sources use a mix of low activity Cs-137 and Am-241/Be, are transported via standard truck, and are small enough that they can be reasonably stored, transported, and used in the field.

The mobile nature of these devices, when combined with the radiological material contained within, make these devices a special concern in the broader context of nuclear and radiological terrorism. Because of this special concern, the U.S. Department of Energy's National Nuclear Security Administration took an interest in pursuing technology that can mitigate the risks that these sources are potentially used in acts of terrorism.

DEVELOPMENT& DEPLOYMENT OF MSTS

The ORS Program began its engagement in developing a solution for mobile sources in 2013 when it solicited requirements from a broad pool of stakeholders in the industrial radiography and well logging industries. These requirements, driven by industry partners' desire to provide enhanced awareness of their devices, kicked off the initial technology development effort led by PNNL. This eventually culminated in initial field deployments of the technology in 2019 where the first iterations of the ORS MSTS system were tested and refined. Lessons learned from these initial deployments were used to engineer more robust solutions which resulted in new versions of this technology from 2020 through 2022 that are now being fielded with source licensees.

Throughout this process, engagement with industry partners led to initial international outreach where the ORS Program began to more formally target deployment opportunities to identify challenges, new development requirements, and further its goals to enhance the security of mobile radiological sources globally. This resulted in initial volunteers in Mexico, Argentina, and Brazil that cover a mix of industrial radiography and well logging partners. Through these early volunteers, several areas of challenges were identified ranging from unique operational requirements to broader technological and cybersecurity-related topics which will continue to present a barrier to broader international deployment if not otherwise overcome.

In addition to traditional domestic and international ORS-led deployments, the program also actively engages with regional and country-level stakeholders to promote the technology and encourage its adoption through the transfer of program-developed technologies. Doing so allows countries and private industry partners with broader regional resources to manufacture, integrate, and deploy MSTS-like systems that only serves to improve the situational awareness of at-risk mobile radiological sources worldwide. These engagements have included Spain, India, and companies that work closely with the Oil and Gas industries in the United Arab Emirates and serve as an alternative model to promoting mobile source security globally.

INTERNATIONAL DEPLOYMENT – LESSONS LEARNED TO DATE

Initial Deployments

Initial international outreach focused originally on Mexico and Argentina. In Mexico, through the ORS program's partnership with a global industrial radiography service provider, a site that used radiography cameras was identified. Through conversations and planning, the first of several challenges was identified: how to integrate the tracking system with industrial radiography cameras in an international environment. Because the tracking system is integrated into the source jacket itself, coordination with source manufacturers and designated source reloaders will be required to sustainably support the installation of mobile tracking systems to these mobile devices.

For well logging, the program's partnership with a global well logging service provider resulted in an initial volunteer in Argentina. This engagement led to several more lessons to be learned as the project team engaged with the site and was exposed to new operational environments that result in the need for further development to account for these needs. One such need is the recognition of the variety of methods for how well logging sources can be securely transported via truck. While in the U.S., wireline trucks (pictured below) are traditionally used, internationally it is not uncommon to use a simple flatbed truck to transport these mobile sources. This has resulted in the need to develop a new container for flatbed trucks that can be outfitted with the requisite mobile source tracking systems that can provide enhanced security and situational awareness to these use cases.

Figure 1, Well Logging Wireline Truck

Finally, more generally, as additional outreach was held with the international community, more requirements were gathered. For instance, the need to make systems more robust for transport containers known as "overpacks" was identified, as these were quickly found to be used in a large portion of international source shipments. Because of this, the necessity to create a more consolidated and stand-alone well logging system with a new suite of sensors and more robust battery capabilities drove additional development and has resulted in several technological advancements that will be used as solutions to these cases.

Figure 2 - Overpack Containers

These are just a few of the general lessons that have been learned from initial outreach and planning for the international deployment of a solution that can help to address the risk of these mobile sources being used for malicious purposes. The following will go into more detail on these challenges, what lessons have been learned to date, and what potential solutions exist to continue moving the needle on broader international adoption of mobile source tracking capabilities.

Summary of Challenges

As mentioned above, systems integration and accounting for novel operational requirements are just a small representation of the hurdles to be overcome before broader international deployment can be accomplished. These include the ability to manufacture and deploy system components at large scale, integrate systems into existing operational protocols, allow communication in signal-challenged environments, and ensure that all communications of such systems are secure and compliant with local and regional requirements. None of these are insurmountable and many have solutions already developed or in the works, but it will take continued, concerted effort to work through them and improve the global security of mobile radiological sources at-large.

Manufacturing & Deployment

As it stands now, the manufacture of MSTS system components is limited to PNNL capabilities. As it is still a relatively new technology that has had so many improvements over the last few years of initial deployments, commercialization has taken some time to get off the ground. As a result, PNNL has been able to support limited domestic deployments. Until there can be confidence in available inventory to support volunteer demand, outreach and install will proceed at a slow pace. However, there are several avenues that can be pursued concurrently to alleviate this challenge.

The first avenue will be to broaden the ability for industry to use ORS funded and developed technology in private sales. This is accomplished through standard commercialization processes and allows companies to license the intellectual property developed by PNNL for their own purposes. This has already been accomplished to some extent with initial partnerships to serve the Latin America region and the United Arab Emirate region. However, to truly expand at a larger and more global scale, additional partnerships will need to be pursued. Until there is robust private manufacturing and deployment in place, there will be a consistent supply-side constraint to addressing mobile source security.

Secondly, working at a country and regional level will be key to broader adoption of mobile source security solutions. It will be important to conduct high-level discussions with countries where the benefits of these security technologies can be discussed, and eventually, the transfer or licensing of ORS-developed technology can be pursued. Doing so will allow each country, regional entity, or local companies to make the technology their own, produced at scale and at a lower cost than would otherwise be possible. ORS has already started these discussions with both India and Spain in pursuit of these goals with the hope that cooperation can be expanded and result in more pipelines of technology development, manufacture, and deployment to continue addressing the risk of mobile radiological sources.

Finally, continued outreach and awareness campaigns to the global mobile source industry will be a factor through all of these avenues. ORS recognizes that private industry is unlikely to take on the burden of production and development so long as a clear demand signal for this technology is lacking. Through participation in international conferences and targeted regional outreach activities, along with efforts to promote strengthening regulations around the use and transport of mobile sources it is reasonable to expect that a demand for this technology can flourish and further incentivize private industry to take on the needed effort.

System Integration

Once the technology is manufactured, the next step is deployment to the sites, trucks, and the mobile sources themselves. As previously stated, part of the current set of mobile source tracking technology includes a module that is integrated into the jacket of an industrial radiography camera known as a Persistent Monitoring Tag or "PM-Tag" which is pictured below. Because this level of integration involves the modification of the jacket itself, which is considered a transport container, and because transport containers for hazardous materials are subject to rigorous design and certification requirements, it has required close coordination with radiography camera manufacturers for both design and for final integration.

Figure 3 - Persistent Monitoring Tag

Domestically, the integration of the PM-Tag is accomplished at the point of source reload. Ir-192 has a half-life of 74 days and sources are typically sent to the manufacturer for reload every 6-8 months, or approximately 3-4 half-lives. When the device is sent for reload, the shielding is removed from the jacket to have its Ir-192 replaced with a new source. When integrating the PM-Tag for a specific device, the manufacturing company will use a jacket with the module integrated and load the shielded source into that before sending it back out to the site. Due to strict quality assurance requirements, source manufacturers prefer that they or a specific vetted vendor performs this action.

Internationally, manufacturers have trusted regional vendors that can perform this same function. In some cases, sites are sent the sources and are empowered to perform these reloads themselves, but this tends to be allowed on a case-by-case basis. To integrate these technology modules more broadly, additional coordination with source manufacturers will be needed. This will be a critical avenue to address and one that can be handled several ways. There is potential that the source manufacturers themselves could include this as a service with reloads as demand grows and technology matures. Absent that, ongoing coordination with these companies will be an essential piece of the overall strategy of more broadly deploying these technologies.

Remote Site Communications

When considering technology that is meant to provide near-real-time information to source owners, the ability for that technology to communicate becomes critical. The oil and gas industries both often operate in extremely remote areas where communication becomes difficult. These challenges can be ameliorated with study and technology, however.

With the expansion of cell phone data capabilities, this is the first option for transmitting signals from mobile source tracking technologies due to its ability to transmit large amounts of data quickly and in a cost-effective manner. However, this comes with shortcomings due to the remote areas that are used for operations. In particular, the lack of reliable cellular service in remote places can render this option ineffective. Mixing in satellite communications is the next option, to allow for signal transmission in these signal-limited regions; however, it does come at a cost and with data limitations. As an example, the solution developed for the Well Logging industry involves a mix of cellular and satellite communications, with the satellite communication module being used as a “last resort” when other data communications cannot be achieved. While these technologies are rapidly improving and becoming cheaper with a broader capability suite, additional study will be required as this continues to evolve.

These studies would need to involve region specific signal mapping that includes a solid understanding of the reach of available cellular communication capabilities and the extent to which satellite communications can help to mitigate the risk that a signal won’t reach its intended destination. Any country looking to make use of this type of technology should consider supporting a study to collect necessary data to ensure that it would be feasible to support a mobile source security system.

Cybersecurity/IT Considerations

Finally, the topic of cybersecurity must be a part of this larger conversation. With this technology comes a necessary back-end structure that involves the creation of data pipelines, aggregation, databases for storage, web-based front ends for reporting, and interfaces that tie all of these necessary pieces together. Because of the nature of this data, it would be sensitive in nature and would require requisite protections as part of the overall information technology infrastructure.

While there are no overarching cybersecurity rules applied consistently globally, there are some regional based governing rules that can be used as an example. The European Union has the

General Data Protection Regulation (GDPR) which governs how data can be used, processed, and stored when involving personal data. Other countries, such as Brazil, have provisions governing when data can move across borders. In Brazil international transfer of data is only allowed under specific circumstances, such as when authorized by the national authority, or it is proven to be necessary to protect the life or physical safety of the data subject (Brazil). Each country will have its own set of laws, policies, and regulations about how to operate and there are a few cases where several countries are united under a single set of rules such as the European Union example.

Navigating this patchwork of regulations can be challenging and drives to the conclusion that a one-sized-fits-all approach will likely not be successful. There must be flexibility in the information technology infrastructure so that it can be more broadly deployed and serve as the backbone to a robust mobile source tracking system. As an example, the ORS-developed system has been created in such a way that it can be deployed through a cloud infrastructure which can be tied to specific regional locations or can be run locally off a server owned and operated by the source licensee. This flexibility will be key to providing a solution that can fit into different cybersecurity environments and continue driving successful deployments of mobile source security technology.

CONCLUSIONS

This paper has covered several challenges to driving the adoption of newer technology to better track mobile radiological sources and mitigate the threat that a lost or stolen source may be used in an act of radiological terrorism. These are not insurmountable challenges. Each one of them has solutions that can be deployed, but it will require a concerted effort amongst radiological security subject matter experts, private industry, regulators, and mobile source owners to continue the development of this technology.

New technology is always an unknown and with that unknown can come a lack of confidence. In just the past two to three years, ORS has worked to prove that the technology works, can be trusted and has identified several lessons learned that will be applied as it continues towards its goal of driving adoption for mobile source security solutions. More lessons will be learned, and more solutions will be developed as these lessons are learned. In collaboration with all stakeholders, the threat of mobile sources being used in an act of terrorism can be mitigated.

REFERENCES

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