A Robot Rodeo for DOE-EM – 18499

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ABSTRACT

As DOE-EM sites grapple with the dull, dirty, and dangerous nature of waste cleanup, emergency response capabilities are critical. But when do sites' emergency response teams have an opportunity to train in real-world scenarios and test their mettle? The Western National Robot Rodeo [1] was conceived in 2007 to provide bomb squads an arena in which to improve their robotics handling skills. This event is now being expanded to support the DOE-EM Technology Development Office's Science of Safety initiative, to better incorporate robotics into their mission space. The Robot Rodeo is a technical competition and capability exercise designed to test an operator's skills, challenge their tactics, techniques, and procedures, and push the boundaries of both man and machine to operate robots near the edge of the manufacturer's specifications. Why? Because, as Lt. General George S. Patton said, *"You fight like you train."* When an incident occurs, response teams and operators will always revert to how they were trained. In DOE-EM's case, the *fight* could be how sites would contain a radioactive material dispersal event, or respond to some other potentially hazardous manmade or natural incident. Is your site prepared for such an event? The Robot Rodeo offers DOE-EM sites an opportunity to participate in annual training to become better prepared to respond. The event allows site emergency response robot operators to be tested and challenged in real-world scenarios (where they can safely fail and try again), so that when an incident occurs they have seen and experienced similar scenarios in training. This hands-on practice is key in preparing an emergency response team to adequately navigate dangerous situations, save lives, and mitigate dire consequences.

INTRODUCTION

Imagine this scenario:

> *Last month, as tornados raced across Alabama, the local nuclear power plant survived a near miss and went off-line and into a safe-mode as designed. To complete some required repairs, the fuel rods were being removed and placed in small batch storage units when it was noticed that Spent Fuel Storage Unit A was leaking highly radioactive cooling water and the radiation sensors in the area were indicating dangerous dose rates. Incident Command has asked your robotic team to help mitigate this situation with the use of your robot. At this time, it is unsafe for additional workers to enter the storage area, due to lethal dose rates and the radioactive water leaking from the storage unit.*
>
> *The Emergency Manager has asked your team to:*
> 1. *Identify the damaged fuel rod;*
> 2. *Coordinate with the reactor operator and re-establish cooling water flow;*

3. *Prevent further contamination.*

Figure 1: Example robot rodeo scenario from 2011 event.

The above scenario was conducted nearly seven years ago during the 2011 Western National Robot Rodeo (WNRR). Although the rodeo scenarios are fictitious, they are based on real-world events. Ironically, this particular Robot Rodeo scenario was developed and designed six months before the Fukushima nuclear disaster, and the Robot Rodeo was held just three months after the disaster that same year. A simple scenario suddenly became a new reality.

To that end, the Western National Robot Rodeo is a competition unlike no other. A weeklong competition where first responders battle using only their robots to solve complex challenging scenarios, the Robot Rodeo is all about testing abilities and developing stronger robot operator skills. This annual event, hosted by Sandia National Laboratories, presents state, local, federal, and military bomb squads with ten challenging scenarios, each 90 minutes long, designed to test and improve their skills using their own bomb disablement robots. Scenarios change each year, and have become increasingly complex. For example, participants at past Robot Rodeos have had to locate and dispose of suspected hazardous materials, locate and move simulated fuel rods from a damaged nuclear reactor, and remove simulated explosives placed by a terrorist in the overhead luggage rack of an airplane.

Through their Science of Safety (SoS) initiative, DOE-EM's Technology Development Office intends to incorporate EM-site-specific needs and challenges into future Robot Rodeos. The

Robot Rodeo is also a major collaborative event bringing together commercial, international, and government partners within the first responder community. Commercial partners bring their newly developed technology to the event, which is often incorporated into a scenario, allowing first responders to get hands-on experience with the latest and greatest technology. In return, the commercial and government partners get direct feedback on their technology, capability gaps, and direct insight to end-user needs. The event also fosters collaboration within the first responder communities in, and around, a facility or site.

ACRONYMS

CST	Civil Support Team
DoD	Department of Defense
DOE	Department of Energy
EM	Environmental Management
EOD	Explosive Ordnance Disposal
HazMat	Hazardous Material
IED	Improvised Explosive Device
PSBS	Public Safety Bomb Squad
RF	Radio Frequency
SNL	Sandia National Laboratories
SOP	Standard Operating Procedure
WNRR	Western National Robot Rodeo

DOE-EM EXAMPLES

John Lee, program manager in the DOE Office of Environmental Management's Technology Development Office, attended and observed the 2017 Robot Rodeo. "It was a great event, well organized and implemented extremely well," John says. "Many of the rodeo's scenarios were applicable to the varied DOE EM missions, and the lessons learned were extremely important. This was quite apparent with the two scenarios designed with the assistance of expert workers from our DOE EM Portsmouth, Ohio, site. It was also a very valuable learning experience for them. We look forward to continuing this valuable collaboration with Sandia, Jake, and his expert team in bringing the best of robotic technologies and training to our DOE-EM sites and mission." [2]

For the 2017 Robot Rodeo, two scenarios were developed specifically for DOE-EM. Scenarios are given a unique, and sometimes humorous, name to help planners and competitors distinguish one scenario from another. A short narrative, or problem statement, is created for each scenario. Once a team arrives at the scenario location and is set and ready to begin, the scenario evaluator reads the narrative. Below are the two narratives that describe EM's two scenarios.

Example #1: Cool it, Hotshot!

> *While United Steel Workers were using their robot for routine cylinder inspections in the processing yard, they discovered several suspicious devices near two Type 48Y UF6 storage cylinders. On-site Emergency Management have called in your support. Working*

with the local bomb squad who responded to your site, your robot response team will be required to;

1. *Work together to take multiple x-rays;*
2. *"Clear" these devices.*

Due to operational RF interference constraints, you are required to operate your robot on fiber, no radios.

Figure 2: The Cylinder Yard

Example #2: What a Mess!

Earlier this morning during normal day-to-day operations, a Criticality Accident Alarm System, or CAAS Alarm, was triggered inside Bldg. X-666. Per procedure, all site personnel were evacuated within a 300m. radius. Working with on-site Emergency Management personnel it has been surmised that the only possible way a CAAS alarm could have occurred inside Bldg. X-666 is that the highly enriched uranium fluid that is piped throughout the building has somehow begun to "pool," or collect, in an unknown way. A waste processing line does pass through Bldg. X-666; however, there are no known locations where a sufficient quantity of radioactive fluid could have naturally accumulated to cause a CAAS alarm. Before sending HazMat personnel into the building, the responding robot

response team is being asked to:

1. *Investigate Bldg. X-666;*
2. *Identify the source of the CAAS alarm;*
3. *Develop a mitigation plan;*
4. *Close all emergency shut-off values, if not already done.*

Steps 1-4 are to be conducted to avoid a criticality event. The local Civil Support Team (CST) has just arrived on scene and is available to support you in any way possible.

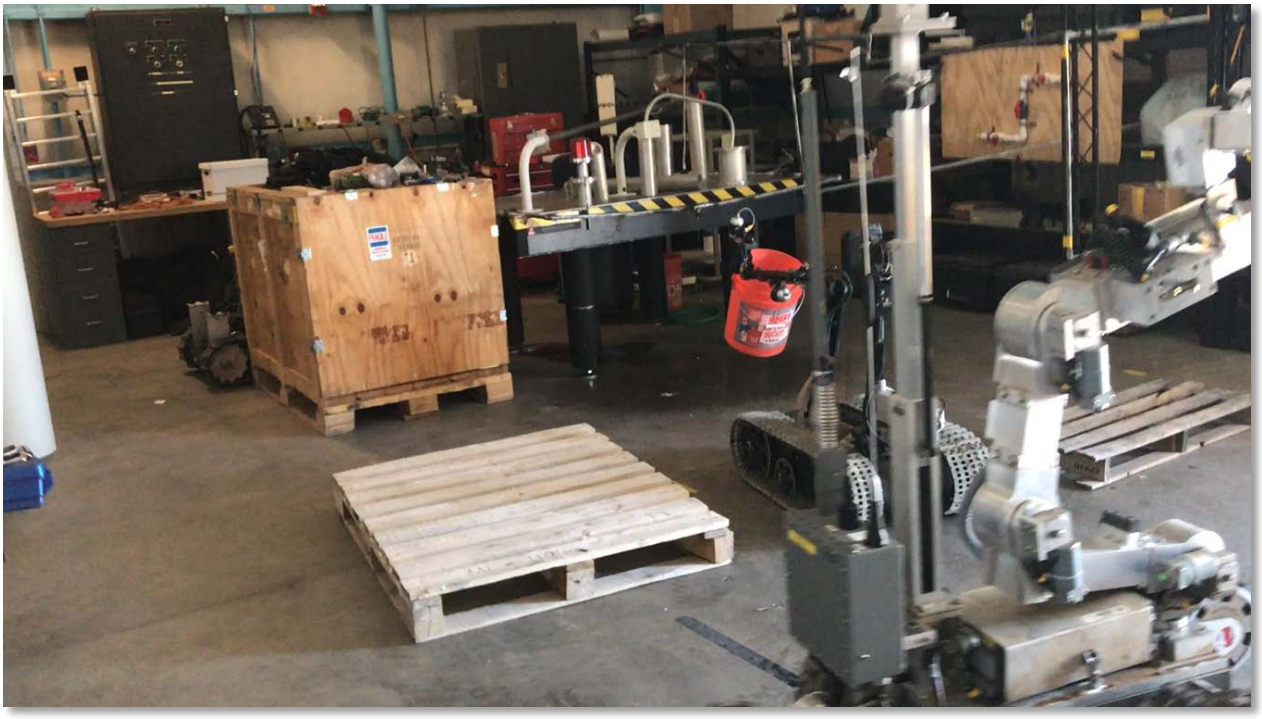

Figure 3: Prevent Further Spread of Hazardous Liquid

Figure 4: Mitigate the Spill

(Please note: Although all scenarios are based on real-life events or derived from what could go wrong at a site, every scenario is fictitious and designed to create challenges and learning opportunities for competitors and participants.)

PURPOSE

Train with Your People

All DOE-EM sites typically have adequate training programs. However, this training tends to be compliance-based rather than performance-based. The Robot Rodeo takes training to the next level by creating an environment for participants to work together as a team. In this setting, teams develop stronger awareness and anticipation of each other's strengths and weakness as related to emergency response. Over the past decade of conducting the Robot Rodeo, Sandia has received feedback multiple times that, although most first responders have some sort of required monthly training, it is not until they compete in the Robot Rodeo that their training and practice move to a higher level.

Train with Your Equipment

Teams in the competition get hands-on training and a chance to hone their skills in a lively, yet low-risk environment. One key ingredient of the Robot Rodeo is that teams must bring their own equipment. This requirement supports an emergency responder's knowledge and understanding of the capabilities—and more importantly, the limitations—of their equipment. Scenarios are intended to push the operator and their equipment to the edge of design and operating

specifications without damaging the equipment. This enables operators to understand the functional limits of their equipment, so they can push it to the edge if necessary during emergency situations.

Over years of conducting the Robot Rodeo, two recurring equipment issues have presented themselves as frequent challenges: power systems and communications equipment. Power systems consist of the primary robot batteries, spares, and charging equipment, batteries and chargers for all ancillary equipment, including OCUs (Operator Control Unit), sensors, cameras, etc. There have been several instances where a team would have two spare batteries, yet both have no load capacity. In other words, a simple voltage check indicates they are in a good/charged condition; however, once the battery is put into service, it only lasts a fraction of the expect operation time. As luck would have it, batteries usually seem to die right when you need them most and when you, the human operator, cannot retrieve the robot to replace the battery. In the Robot Rodeo, a team might lose 5 points as a penalty if they need to approach the robot to change batteries and continue with the scenario. But in real life, this is not an option and would most likely compromise the mission.

Communications are crucial and can pose an enormous challenge. If an operator cannot communicate with, i.e., control, their robot, they have no robotic response capability. Robot communications are either conducted through RF (radio frequency) communications or via a tether, usually a fiber optic cable. Depending on the scenario, operators must decide before proceeding with the mission which form of communication they plan to use. RF communications provide the least restrictive environment for maneuvering the robot, because there is no tether to get tangled up in or cut. However, some environments can be very ‘noisy’ from an RF perspective, which might inhibit consistent communication with the robot. Also, if multiple robots are deployed during the mission and they are all using RF communications, one robot’s signal will most likely interfere with another robot’s, which can render it essentially useless.

The potential RF challenges might push an operator to opt for always using a fiber optic tether. Fiber does have many advantages such as crystal-clear communication, essentially unlimited bandwidth for multiple cameras, sensors, etc., and no complications from RF interference or jamming. However, the big disadvantage for operating with a tether is the tether itself. During a mission, an operator must be extremely careful not to inadvertently cut the tether. If the tether is cut, the robot will stop operating which immediately ends the mission. To give operators practice with tether management, many Robot Rodeo scenarios force teams to operate with a tether.

Train with Your Local Responders

The title song to the 1984 movie “Ghostbusters” had the infamous catchphrase, “Who you gonna call?” When it comes to emergency response, that catchphrase is extremely relevant. Once DOE-EM site Emergency Management personnel are alerted to a potential problem, who should they call? If the situation does not warrant a 911 call, then they might call their robot response team. The response team must understand who exactly will be on call, where the robot is stored, whether the batteries are charged, and whether the equipment is mission-ready.

If a situation requires external help, sites will typically call their local Emergency Management Services (EMS) which may include some, or all of, the following depending on the severity of the incident:

- Local hospital,
- Fire department,
- Hazmat team,
- Bomb squad.

Scenarios like this require a high degree of interoperability, i.e., collaboration between civilian and miltary agencies. As an example, the picture below was taken during the 2017 WNRR and depicts the collaboration of three separate entities working together to solve a common problem.

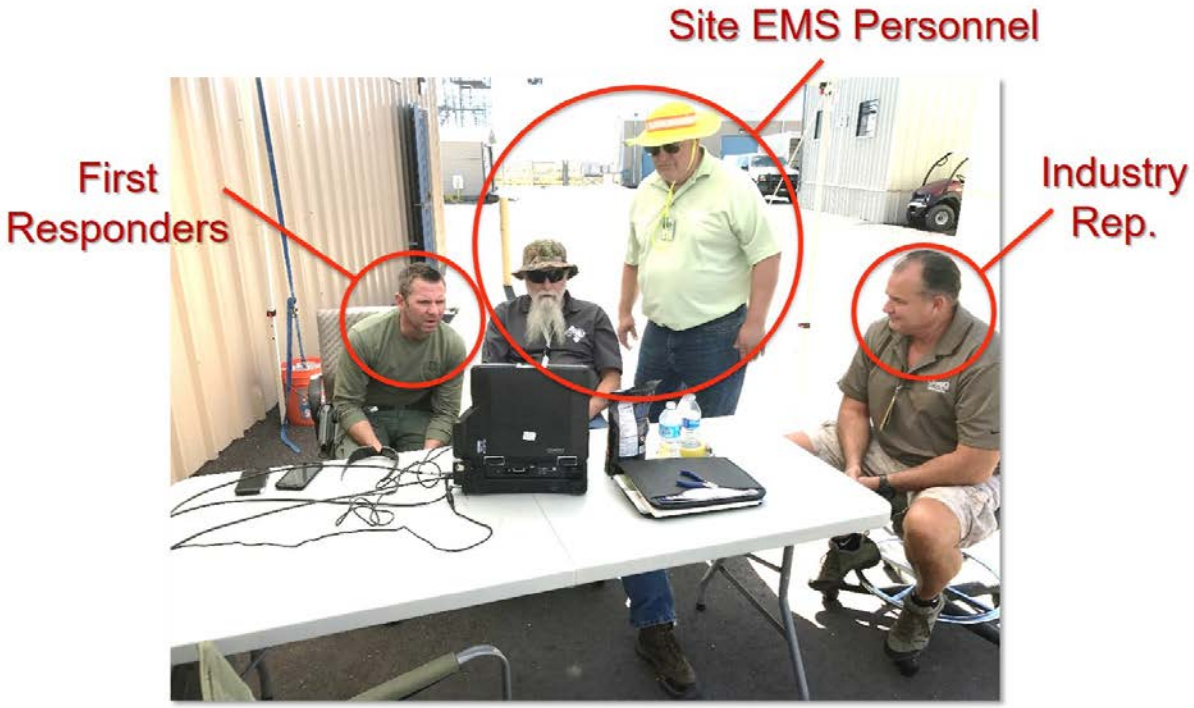

Figure 5: Collaboration between multiple entities

Next, if the emergency event is large enough, the state's Civil Support Team (CST) may be required [2]. Who, specifically, is this? Do you know the captains name, phone number, etc.? Have you meet face-to-face? Has he/she ever toured your facility to become familiar with your site's hazards and potential response locations and needs? One could also consider contacting the nearest military installation for help. Again, do you know who to call? Have you met and trained together?

"We keep coming back to the Robot Rodeo because it's a training opportunity that really pushes our skill set with the robots," says Sgt. Carlos Gallegos, commander of the Albuquerque Police Department's bomb squad, whose team attends the rodeo every year and has won twice. "We

appreciate Sandia National Laboratories for taking the time to put on such a beneficial week for the local bomb squads." [2]

Finally, the camaraderie developed during the Robot Rodeo is priceless. Often, teams who come to compete against each other quickly begin to share their successes, failures, and tactics, techniques, and procedures (TTP). This forms the basis of an informal Lessons Learned program.

Train in Realistic Scenarios

Emergency response teams usually have a monthly requirement to do some type of hands-on proficiency training. But an emergency response unit or squad must be disciplined to make this limited training time effective. Often, teams report that their home site training tends to be stale and repeative. The fresh and relevant training offered by the Robot Rodeo is what keeps teams coming back year after year. For example, during the 2017 Robot Rodeo, one scenario required teams to use robots to unstack six labeled orange cones and then arrange them to spell out a word. "Traffic cones are hard for robot grippers to grab, requiring just the right amount of strength and finesse," says Tech. Sgt. Joshua Rickert of Kirtland Air Force Base 377th Explosive Ordnance Disposal Flight and an evaluator for the scenario. "Though it is unlikely that bomb squads will encounter this exact situation, the dexterity tested will be helpful in whatever they do have to handle," he says. [2]

When designing sceanrios, Sandia follows a general guideline that 25% of sceanrios can be basic robot operator proficencey training through obsitcle course like sceanrios. The remaining 75% of sceanrios are taken from real-world events. Given the time limitiation of a 90-minute scenario, Robot Rodeo sceanrios focus on a specific aspect of an event to highlight a particular training objective. On occasion, a more challanging or difficult sceanrio is developed that requires more time. In this case, a double sceanrio is created. Double sceanrios can take anywhere up to 180 minutes and require two teams to work together to accomplish an objective, or two teams to compete in a head-to-head event to score points. Not only does this appeal to the competiveness of participants, but more importantly it fosters interagency collaboration.

Finally, if a scenario is going to be truly challanging, it must also be safe and non-threatning for both the operator and the equipment. To ensure safety of all participants and equipment, all Robot Rodeo scenarios are overseen by a safety coordinator.

BENEFITS

Critical Thinking

A challenge each year in developing new scenarios is to create situations that will challenge an operator's normal thought process. To help develop critical thinking skills for first responders, scenarios are developed to force teams to try new and innovative approaches. For example, in the scenario pictured below teams are presented with a dilemma: should they rescue the two downed first responders (fire fighters) or stop the spread of the hazard (a chlorine leak)?

Figure 6: Hazardous Chemical Spill Scenario with injured First Responders

Interestingly, different teams tend to tackle an identical problem in many different ways. As the Robot Rodeo progresses, each scenario evaluator (the person assigned to conduct and score the scenario) keeps track of the various approaches used and shares this during a Lessons Learned session at the end of the event.

Operations Planning

The Robot Rodeo provides teams with a unique opportunity to hone their Standard Operating Procedures (SOP). Many civilian bomb squads are considered part time squads, which means some bomb techs hold a primary job as a patrol officer, for instance, and a secondary role as a bomb technician. The same could be said for DOE site robot response teams. Their primary job is most likely focused elsewhere in the site's daily operations, but they are asked to respond as a robot operator only in the case of an event. In these cases, an operator is required to know their normal job operations and also maintain their emergency response skills.

The Robot Rodeo helps operators practice and maintain their emergency response procures, so they become second nature and are primed for a real-world emergency event occurs. Of course, a

real-world event is not the time to be looking up procedures, or trying to remember which is the best approach for turning a shut-off valve, opening a door, or how not to cut their fiber tether. Operators must practice these maneuvers many times until they can quickly respond appropriately.

The figure below depicts a scenario involving the removal of a suspicious device from a site utility access tunnel or coolant drain spill way. As a team prepares to respond to this scenario, they should be deciding 1) whether to use radios or fiber, 2) whether to use a large, medium, or small robot, and 3) how the robot should be configured with respect to cameras, sensors, or other possible fixtures or jigs.

Figure 7: Underground Utility Access Tunnel or Drain

Operator Proficiency

As mentioned previously, most scenarios are based on real-world events, but a few are essentially operator proficiency challenges. These challenges are designed to help operators develop skills by navigating an obstacle course. The figure below illustrates an example of one such obstacle course. The course consisted of the following challenge elements:

1. *Navigate a narrow 5m long hallway, with only 5cm of clearance on either side of the robot's wheels;*
2. *Pickup a toy throwing disc;*
3. *Place this toy disc on a 2m tall hat stand;*
4. *Drive your robot up onto an elevated, confined platform (see picture below);*
5. *Cross from one platform to another via the 3m long wooden beams*
   Note: The beam spacing was set to each team's robot specific wheel/track spacing;
6. *Once across the beams, dismount the confined platform;*
7. *Pickup a mouse trap that is energized or 'set' (i.e., the spring is engaged and ready to clap shut);*
8. *While still holding the energized mouse trap, drive 3m cross a field of used automotive tires (to simulate a rough and repeatable terrain) ;*
9. *Once safely across this rough terrain field, set down the mouse trap without releasing the spring.*

   To make this especially challenging:

10. *Do all of the above steps with a visual barrier between your eyes and your hands so that you, the operator, cannot see your hands nor your robots many control knobs, switches, levers, and joysticks.*

This scenario was created to help operators develop muscle memory. Much like a person who is considered a touch-typist or concert pianist who does not need to look down at their hands while playing, a robot operator must know where all of the robot's controls are by feel. To respond efficiently during a real-world event, operators must act instinctively, which requires a great amount of practice.

Figure 8: Operator Proficiency Challenge

LESSONS LEARNED

At the end of each Robot Rodeo, a Lessons Learned briefing is conducted with all teams, scenario evaluators, vendors, visitors/observers, and other participants.

First, evaluators are given the opportunity to describe what they observed regarding their scenario and how each team approached the same problem. They share what worked, and what did not work. This allows a team who might have struggled to learn from a team that did well. Generally, a best practice or approach evolves for each scenario, and it is beneficial to reflect on this as a group.

Next, team captains describe what worked and what did not work so well for their team. This phase of the Lessons Learned briefing often helps identify technical challenges. It is at this point that DOE-EM's Technology Development Office (TDO) has the opportunity to turn these identified short comings and technical challenges in to requirements for research and development.

Key lessons learned include:

1. Make sure your emergency response robot(s) and all supporting equipment are properly maintained and stored in a state of readiness.

2. Make sure your operators are given adequate time to practice and develop their robot driving skills.

3. Train with your entire emergency response community – site specific, local community, and state or regional assets, both civilian and military.

CONCLUSIONS

The Western National Robot Rodeo provides the opportunity for emergency responders to participate in critical training and teambuilding. The week-long technical competition and capability exercise is designed to pit emergency response teams against each other as they battle real-world, emergency response scenarios utilizing their own robotic equipment. By doing so, teams gain valuable experience and ultimately become better emergency responders. Because the Western National Robot Rodeo embodies the spirit of DOE-EM's Science of Safety initiative, the event is being expanded to support the DOE-EM Technology Development Office in better incorporating robotics into their mission space.

REFERENCES

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