A Robot Rodeo for DOE-EM – 18499 (DRAFT)

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ABSTRACT

As sites grapple with the dull, dirty, and dangerous of their own emergency response capability, where do they have an opportunity to truly test their mettle? Lt. General George S. Patton, who was preparing the Third Army prior to the Allied invasion of France during World War II, was once quoted as saying, *"You fight like you train."* In this case, the 'fight' could be how your DOE-EM site will fight to contain a radioactive material dispersal event, or respond to, some other potentially dangerous or hazardous manmade or natural incident that has occurred. Is your site prepared for such an event? The Western National Robot Rodeo [1] was conceived in 2007 to provide bomb squads an arena in which to improve their robotics handling skills. The robot rodeo 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. More specifically, the goal is to get EM sites to participate in the annual event to become better prepared to respond. The Western National 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 the robot very near the edge of the manufactures specifications. Why? Because, when an incident occurs and a site is in 'response mode,' operators will always revert to how they were trained. Therefore, as much as is practical site emergency response robot operators must be tested and challenged in real-world scenarios and be allowed to fail and try again so that when, not if, an incident occurs they've seen and experienced worse in training. Only then will an emergency response team be able to adequately mitigate dangerous situations and potentially 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 is leaking highly radioactive cooling water and the radiation sensors in the area are 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 eight years ago during the 2011 Western National Robot Rodeo (WNRR), and although the rodeo scenarios are fictions, they are based on real-world events. Ironically, in this particular case, this robot rodeo scenario was developed and designed six months prior to the Fukushima nuclear disaster and the 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, is all about testing abilities and ultimately becoming better robot operators. This annual event, hosted by Sandia National Laboratories, presents state, local, federal, and military bomb squads with ten challenging scenarios, each 90 minute long, designed to test and improve their skills using their own bomb disablement robots. Scenarios change each year, and have become increasingly complex. In the past, participants 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, EM's Technology Development Office wants to incorporate EM site specific needs and challenges into this event going forward." 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 latest and greatest technology to the event, which oftentimes is incorporated into a scenario, allowing first responders to get hands-on experience with the newest technology. The commercial and government partners get direct feedback on the technology, capability gaps, and end-user needs. The event also fosters collaboration within the first responder community 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

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.

John Lee, program manager in the DOE Office of Environmental Management's Technology Development Office, attended and observed this year's 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."

Example #1: Cool it, Hotshot!

> While United Steel Workers were using their robot for routine cylinder inspections in the processing yard, they discover 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, and
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, and
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 possible.

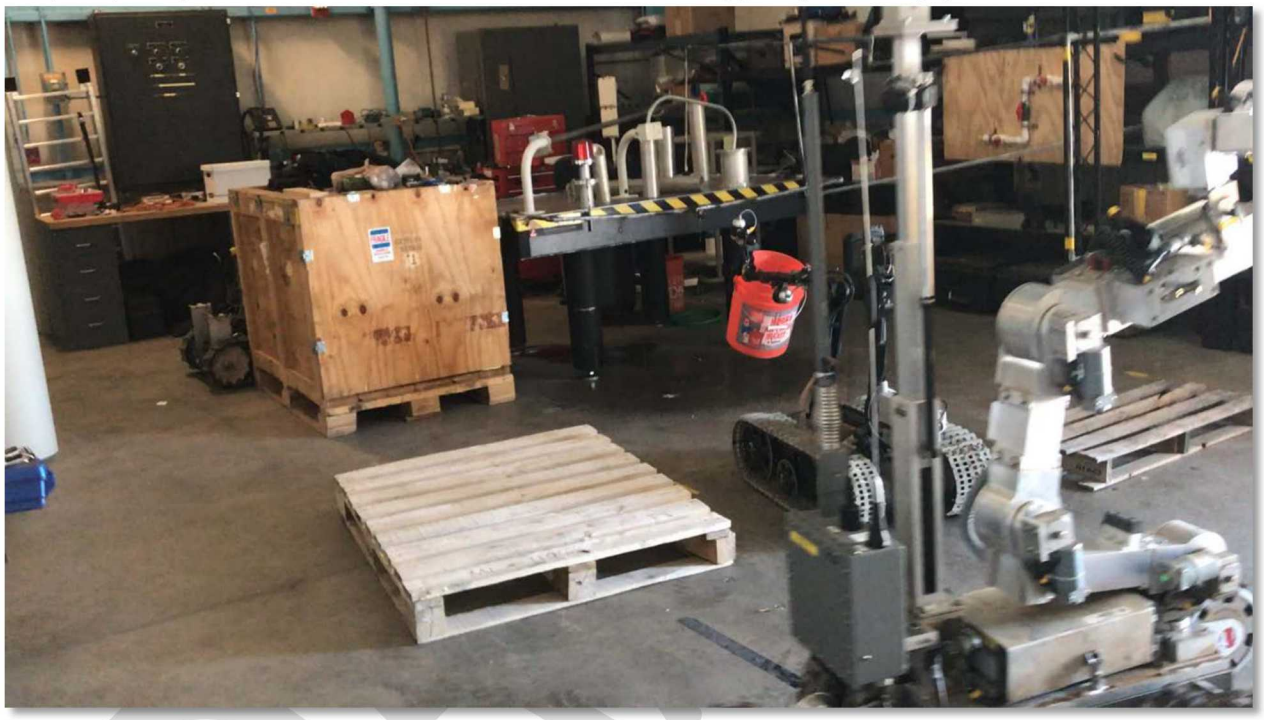

Figure 3: Prevent Further Spread of Hazardous Liquid

Figure 4: Mitigate the Spill

This is a good time to remind the reader that even though all scenarios are based on real-life events or derived from what could go wrong at a site, the scenarios are fictitious and designed to create challenges and learning opportunities for competitors and participants.

PURPOSE

Train with your people

Practice, practice, practice. All DOE-EM sites typically have adequate training programs; however, this tends to be more compliance based rather than performance based training. What is proposed here is to take the training to the next level of effectiveness by working together as a team, or unit, and being able to anticipate and know each other's true strengths and weakness as it relates to emergency response. One key goal of the robot rodeo is to 'force,' through good peer pressure via an inherent competitiveness to win, a team to not just practice together, but to truly train together. Over the past decade of conducting the Robot Rodeo, it has been relayed to Sandia multiple times that even though most first responder teams have some sort of required monthly training, it is not until they are competing in a Robot Rodeo does their training move to a higher level. This is exactly what we want and expect from the Robot Rodeo.

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 each team that comes to

compete must do so with their own equipment. An emergency responder must know and understand the capabilities, and more importantly, the limitations of their equipment. Scenarios are created that push the operator and their equipment to the edge of design and operating specifications without damaging the equipment. Another way to state this is, if you do not know where the operational edge is, you will not know how far you can push your equipment.

A lesson learned from years of conducting the robot rodeo highlights two recurring equipment issues; 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. And, as luck would have it, it usually dies right when you need it most and when you, the human operator, cannot retrieve the robot to replace the battery. In the 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.

Not to state the obvious, but if you cannot communicate with, i.e., control, your robot you have no robotic response capability. Robot communications are either through RF (radio frequency) communications or via a tether, usually a fiber optic cable. Depending on the scenario the operator must decide before proceeding with the mission which form of communication they plan to use, RF or fiber. RF communications provide the least restrictive environment for maneuvering the robot, i.e., there is no tether to get tangled up in or cut. However, some environments can be very ‘noisy’ from an RF perspective and might not provide consistent communication with the robot. Also, if multiple robots are employed during the mission and they are all using RF communications, one robot will most likely interfere with another robot rendering it essentially useless.

The potential RF challenges might push one to always use a fiber optic tether. Fiber does have many advantages such as crystal-clear communication, essentially unlimited bandwidth for multiple cameras, sensors, etc., and is not subject to RF interference or jamming. The big disadvantage for operating with a tether is the tether itself and not inadvertently cutting the tether. Once the tether is cut, the robot will stop operating. End of mission. Therefore, many scenarios are created that force the teams to operate with a tether to train on ‘tether management.’

Train with your local responders

In the title song to the 1984 movie “Ghostbusters” it had the catchphrase of, “Who you gonna call?” That catchphrase is extremely relevant regarding an emergency response, so let’s explore this from a site perspective. Once DOE-EM site Emergency Management personnel are alerted to a problem, or potential problem such as a suspicious package, whom might they call? If the situation does not warrant a 911 call, then they might call their robot response team. Who, exactly, is on call, where is the robot, are the batteries charged, is the equipment ready to go?

Now, let's assume the 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

As an example of this, the picture below was taken during the 2017 WNRR and depicts the collaboration from three separate entities all working together to solve a common problem.

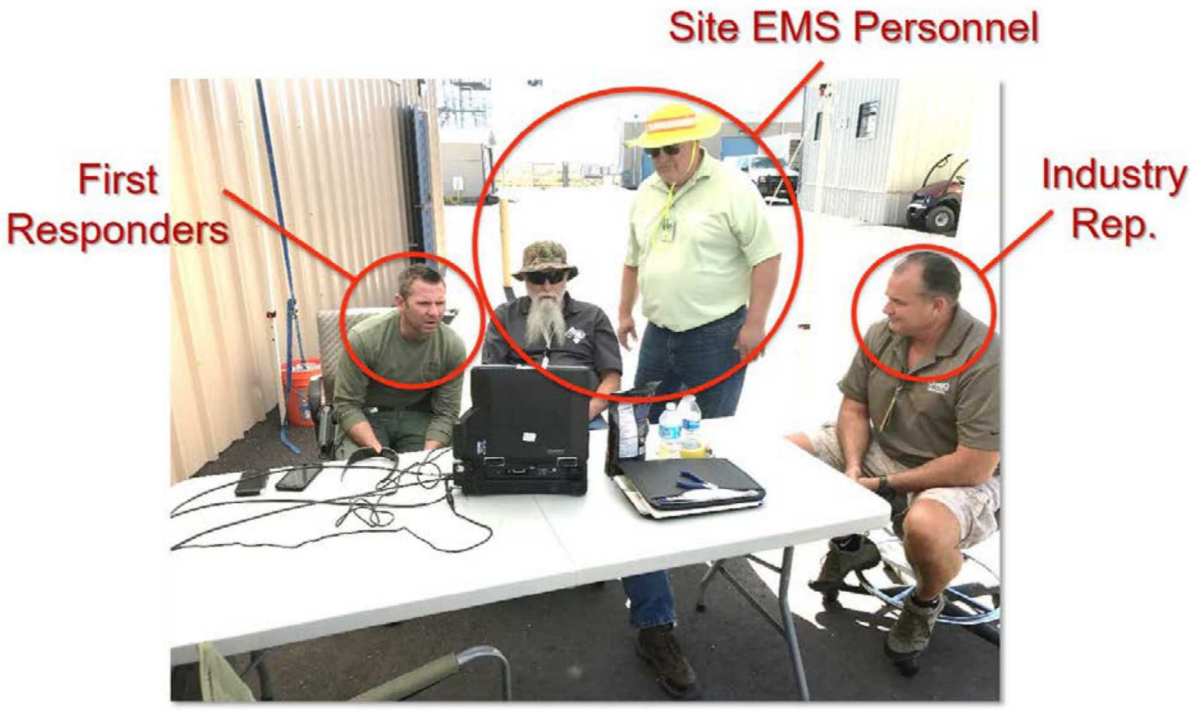

Figure 5: Collaboration between multiple entities

Next, if the 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 has attended the rodeo every year and won twice. "We appreciate Sandia National Laboratories for taking the time to put on such a beneficial week for the local bomb squads."

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

Train in realistic scenarios

This is key. Emergency response teams usually have a monthly requirement to do some sort of hands-on proficiency training. The problem is an emergency response unit, or squad, must be disciplined to make this limited training time effective. What we hear from teams is that their home site training tends to be stale and repeative. This requirement for relevant training is what keeps teams coming back year after year to the robot rodeo. For example, during the 2017 Robot Rodeo on scenario the robots needed 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 bomb squads will encounter this exact situation, the dexterity tested will be helpful in whatever they do have to handle, he says.

When sceanrios are in the design phase we follow 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 sceanrio, 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 to agency collaboration. To take this one step further it also addresses interoperability, i.e., collaboration between civilian and miltary agencies.

Finally, if a sceanrio is going to be truly challanging it must also be safe and non-threatning for both the operator and the equipment. First, the operator needs to know that neither he nor any one from their team will be injured during the event. Just as important, an operator needs to know that none of their equipment will get damaged or broken during the event either.

BENEFITS

Critical Thinking

A challenge each year in developing new scenarios is to create ones that will challenge an operators normal thought process. The cliché is “Think outside the box,” and we want to develop critical thinking skills for the first responders. Therefore, scenarios are developed and presented to teams that will force them to try new and innovative approaches. For example, in the scenario

pictured below teams are presented with a dilemma. Do 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

What we find throughout the event is that with as many teams as are competing, these will same teams will tackle the identical problem in as many diverse ways. As the robot rodeo progresses, each scenario evaluator, the person assigned to conduct that scenario, keeps track of the various approaches used and shares this during the after-event Lessons Learned session.

Operations Planning

The robot rodeo also provides teams with a unique opportunity to hone their Standard Operating Procedures (SOP). Many civilian bomb squads are considered part time squads. What this means is that for some bomb techs their primary job might be as a patrol officer first and then as a bomb technician. The same could be said for DOE site robot response teams. Their primary job is most likely somewhere else in the site's day to day operations, and then they are asked to respond as a robot operator only when there is an event. Therefore, not only would a person be required to know their normal job operations, but also their emergency response operations.

The problem is, which do they do more; day to day operations or emergency response operations? The answer is obvious and it highlights why events like the robot rodeo are so important to cause teams to practice, practice, and still practice their emergency response procures. These skills need to become second nature, and unfortunately robot driving is a perishable skill. When a real-world emergency event occurs, this is not the time to be looking up procedures to determine what to do, nor try to remember which is the best approach for turning a shut-off valve, opening a door, or how not to cut their fiber tether. They must have practiced all of these maneuvers many times until it feels natural and 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 the teams prepares to respond to this scenario they should be deciding if they are 1) going to use radios or fiber, 2) going to use a large, medium, or small robot, and 3) how will the robot be configured with respect to cameras, sensors, of other possible fixtures or jigs.

Figure 7: Underground Utility Access Tunnel or Drain

Operator Proficiency

As mentioned previously, all scenarios are based on real-world events, though one or two are essentially operator proficiency skill challenges. We design challenges to see who's has the best robot operating skills and this is most easily accomplished through an obstacle course. The figure below helps illustrate 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.

   Now comes the hard part:

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.

Why would we create such a scenario? The answer, muscle memory. Much like a person who is considered a touch-typist or concert pianist who does <u>not</u> need to look down at their hands, a robot operator needs to know where all of the robot's controls are by feel or what we call muscle memory. For example, during a real-world event it is not the time to be looking down at your robot's control box to find the switch or knob used to open the robot's gripper. This operation needs to be instinctive and the only way for it too become instinctive is to practice, practice, and practice.

Figure 8: Operator Proficiency Challenge

LESSONS LEARNED

Every year at the end of rodeo week a Lessons Learned briefing is conducted with all teams, scenario evaluators, vendors, visitors/observers, and other participants.

Phase #1 – Evaluators for each scenario are given the opportunity to describe what they saw 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 on a particular event to learn from a team that did well. What we find is that a best practice or approach does evolve for each scenario.

Phase #2 – Team captains described what worked and what did not work so well for them. It is usually at this phase of the lessons learned briefing that technical challenges are identified. It is at this point that 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.

Here are the key lessons learned:

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.

4. Find a EM robot rodeo near you and compete!

CONCLUSIONS

The Western National Robot Rodeo is a week-long technical competition and capability exercise designed to pit emergency response teams against each other as they battle real-world, emergency response scenarios utilizing their own robotic equipment with a goal of ultimately become better emergency responders. The robot rodeo 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. More specifically, the goal is to get EM sites to participate in the annual event to become better prepared to respond. As sites grapple with the dull, dirty, and dangerous of their own incident response, where do they have an opportunity to test their response skills?

The Robot Rodeo is designed to test an operator's skills, challenge their tactics, techniques, and procedures, and push the boundaries of both man and machine to operate the robot very near the edge of its capabilities, all in a safe, yet challenging, environment. It is a known fact that when an incident occurs and a site is in 'response mode,' operators will always revert to how they were trained. Therefore, as much as is practical site emergency response robot operators must be tested and challenged in real-world scenarios, and be allowed to fail and try again so that when, not if, an incident occurs they've seen and experienced worse in training. Only then will an emergency response team be able to adequately mitigate dangerous situations and potentially save lives and mitigate dire consequences.

The Western National Robot Rodeo embodies the spirit of EM's Science of Safety initiative.

REFERENCES

1. www.sandia.gov/robotrodeo

2. https://www.nationalguard.com/guard-experience/civil-support-team