Semantic Web Technology for Training to Meet a Changing Threat

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ABSTRACT

An Operational Adaptive Training System (OATS) using operational intelligence sources can give First Responders, from bomb disposal teams to firemen and law enforcement officers, the ability to maintain their operational edge in an era of constantly changing threats. The traditional approach of infrequent attendance at residential training and lagging responses to rapidly changing threat warnings is not sufficient to keep up with the evolving threats. Most agencies cannot afford to send their officers to more frequent residential courses to catch up, even though the gap means more risk in terms of preparedness and First-Responder safety. An OATS uses distributed learning technology to provide up-to-date training to First Responders anywhere they have access to a computer and can a secure link to the Internet.

The Internet provides key infrastructure for an OATS. It allows schools to access streams of operational intelligence data from around the world. Similarly, it allows those schools to analyze that data and distribute up-to-date training materials to any agency using Learning Management Systems. The weak link is the transformation of the analyzed intelligence data into training materials, which is a costly, labor-intensive process that requires centralized peak-load staffing to maintain responsiveness.

This paper describes research on emerging Semantic Web technologies to identify and isolate changes in training materials based on the analysis of incoming intelligence information. An ontology is used as a requirements traceability model to capture generic training requirements and link them to training assets. The incoming data is processed to determine which requirements are affected and to identify the assets to be modified. Critical tasks and performance measures are updated, as necessary, to meet the new intelligence, and simulation-based initial conditions and assessment methods are generated for these measures.

ABOUT THE AUTHORS

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[1] RTI International is a trade name of Research Triangle Institute.

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INTRODUCTION

Law enforcement agencies in the United States and abroad must respond to global terrorist organizations that are frequently changing their technologies and tactics. The rapid evolution of improvised explosive devices (IEDs) is an example of the interaction between advancing technologies and tactics. As new technologies for remote detonation of IEDs are developed and applied tactically, appropriate countermeasure technologies must be designed and tested, and then tactics for the use of these countermeasures must be developed and disseminated to the First Responders, who will have to deal with these devices. When our adversaries observe that their detonation method no longer works, they quickly adopt new technologies and tactics, and the cycle repeats itself.

An Operational Adaptive Training System (OATS) uses operational intelligence sources, scenario-based training, and Web browser technology to provide up-to-date training to law enforcement officers anywhere they have access to a computer and a secure link to the Internet. Key to the success of an OATS is the ability to rapidly update training materials based on lessons learned from the field.

This paper describes research on methods to support an OATS, including emerging Semantic Web technologies to identify and isolate changes in training materials based on the analysis of incoming intelligence information. This paper also describes ongoing efforts with the Federal Bureau of Investigation (FBI) Bomb Data Center (BDC) to implement an OATS at its Hazardous Devices School (HDS). The FBI BDC administers the FBI HDS at Redstone Arsenal, Alabama, which provides certification and re-certification training for all civilian bomb squad technicians and commanders.

LAW ENFORCEMENT TRAINING METHODS

Law Enforcement Need for Sustainment Training

Many law enforcement agencies have problems keeping their staff up-to-date on procedures, technology, and changes in threats and the operational environment. For small agencies, the loss of available personnel attending institutional training at remote locations stretches their personnel resources dangerously thin. Often, this challenge is compounded by the cost of the travel and lodging. Most law enforcement agencies have been able to meet training requirements for the slowly evolving threat and operational environment of normal criminal operations where training can be adjusted to accommodate the local agency's schedule. However, the global war on terrorism has placed bomb disposal personnel in a situation where rapid change in the threat has made previously safe training processes dangerous.

Residential Training for Certification

The standard process for First Responder training is residential training and certification followed by continuing education and periodic qualification on selected skills, such as handling firearms or lifesaving. This approach benefits from highly effective experiential training through hands-on practical exercises under the watchful eye of experienced instructors. Most agencies have adjusted their budgets and hiring practices so that they can afford initial qualification costs.

Update Bulletins for Monitoring the Threat

The predominant method for notifying the field of changes in hazardous device threats and tactics is through notices communicated through various law enforcement intelligence systems. Although this method gets the data out to the field rapidly, it places the burden of converting this information into practice on the agency receiving the information. Local law enforcement agencies also have to consolidate information from various sources, which involves redundant, labor-intensive efforts by many agencies.

Adult learning theory also emphasizes that just reading notices is not an effective method for learning new procedures or changing well-established habits that are now dangerous.

Residential Training for Maintaining Currency

A second method to keep law enforcement agents current on hazardous device threats is through periodic institutional training. This approach suffers from the lag time between the notification of the change in threats to the implementation of the countermeasure training at the institutions. A second delay results from the lag in scheduling the training for the local agency staff members. As indicated above, many law enforcement agencies cannot afford the personnel time or the travel expense associated with the frequent institutional training required to keep bomb disposal personnel trained, even when a federal agency pays for the training development costs as well as the instructor salaries and institutional costs.

NETWORK-ENABLED TRAINING

The Internet and low-cost personal computers are the basis for potential alternatives to institutional training. In the following sections, we discuss their capabilities for rapidly informing law enforcement training institutions of changes happening in the field and for widely disseminating engaging and up-to-date training materials.

Using the Internet for Collecting Lessons Learned

The FBI BDC collects, analyzes, and distributes bomb incident information to public safety officials through Special Technical Bulletins, Investigator Bulletins, General Information Bulletins, and Statistical Digests, both in print form and through the Law Enforcement Online Web site (see FBI BDC, 1998 for an example). FBI BDC personnel, along with HDS faculty and staff, continually monitor lessons learned distributed over the Internet by various intelligence sources. Access to these streams of information put the FBI HDS in a unique position to implement adaptive operational training.

Using the Internet for Distributing Training

The FBI HDS is in the process of acquiring and configuring a Learning Management System (LMS) to provide downloads and automatic updates of training materials. The LMS student record-keeping will allow virtual training to be downloaded in the field and then allow instructors to upload student performance records before students arrive for residential recertification training. One of the goals is to use virtual training as a gate to sort students into two tracks: a standard recertification track and a basic skills track for students who need prerequisite training before they enter the recertification track. Success in the basic skills track or high scores in the distributed virtual training will be required for entrance to the recertification track. Success in the field exercises of the recertification track will be required for a student to be recertified. This approach will allow more focused and efficient recertification training and reduce overall recertification costs. Students may elect to work to achieve high scores on the virtual training at their offices before attending the institutional training as a way of reducing travel and substitute personnel costs for the sponsoring agency.

Sharable Content Object Reference Model

The FBI HDS wants to leverage training content developed by other federal agencies and academia for its distributed training. Key to reusing other training materials is implementing standards that will allow training content from multiple sources to be combined into a single course. Therefore, they are converging on standards such as the Sharable Content Object Reference Model (SCORM) to make this reuse feasible.

The SCORM is designed to allow units of learning content (called Sharable Content Objects [SCOs]) to be stored, configured, and distributed by any LMS meeting the SCORM's standards and viewed by any client computer with a standard Web browser (Dargue et al., 2006). The SCORM provides a standard way to download SCOs to a client Web browser and a standard way for SCOs to communicate with the LMS. The SCORM is designed around the representation of a course as a hierarchy of learning activities. It associates learning objectives with the learning activities. The SCORM provides methods for navigating around the learning activity hierarchy and roll-up functions to calculate student assessment measures based on the learning objectives.

Web-Delivered Virtual Training

Virtual training is an attractive method to help law enforcement personnel keep abreast of new threats. Virtual training allows the student to practice procedural skills in a variety of scenarios. Deliberate practice is known to be an effective method for adult learning. Scenario-based training provides the student

with an appropriate context for understanding the implications of new threats.
Virtual training is executed using computer-generated simulators with models of operational systems and vehicles. Virtual training simulations can be organized as simulations of collections of objects. The simulated nature of these training experiences means that hazardous scenarios can be trained realistically and safely.

The increasing capabilities of personal computers to support games and high-resolution graphics, as well as the availability of high-speed Internet connections to law enforcement agencies, make the delivery of virtual training to the police station feasible. This is an essential requirement for implementing an OATS. However, the development of scenario-based training is typically time-consuming and expensive.

Virtual environments are by nature object-oriented systems, which makes it easy to add or delete objects. The more difficult challenges are aligning the scenarios with the appropriate learning objectives and providing the appropriate student performance assessment and feedback based on student actions rather than a multiple-choice exam. A class hierarchy of object behaviors with inherited methods can help to minimize the changes needed to represent a new type of device. Similarly, associating formal structures and parameters with the scenario definitions allows rapid updates in training in response to new terrorist tactics.

Learning Management Systems
An LMS provides several key capabilities for an OATS:

- A portal that provides the law enforcement agent with access to online courses, 3-dimension (3-D) simulations, and other digitized training materials.
- A collaborative environment for the production and review of new training materials and courseware.
- A database of detailed training records that allows the schoolhouse to track each student. Using the capabilities of the SCORM, the LMS should support automated tracking of the progress of each student on Web-delivered training materials.

SEMANTIC WEB TECHNOLOGY

Ontology

Ontologies are increasingly prevalent, in part due to the needs of the Semantic Web (Sicilia, 2005). Ontologies are beginning to be used for military applications (Lacy et al., 2005), including definitions for the description of explosive devices. Ontologies are also being used to describe modeling and simulation configurations (Lacy and Henninger, 2003) and are being applied to describe training system configurations and associated risks (Frank, Hubal, & O'Bea, 2007).

Ontologies are defined in terms of entity-relationship models, the attributes associated with the entities, and class hierarchies of rules defining instances of entities and instances of relationships The combination of entity relationships and attributes allows the ontology to communicate with source databases to obtain initial attribute values. This is particularly valuable when the entity-relationship diagram represents a schema that covers multiple source databases. In this case, the ontology serves as an interface between multiple databases by determining keys to extract and join matching information from the associated databases.

The class hierarchies of rules allow the ontology to process hierarchical structures, such as taxonomies. The rules of an ontology are used to compute derived attribute values (e.g., using the hierarchy to compute risk attributes). The rules can also be used to determine under what circumstances the abstract relationship is inherited to elements of the taxonomies connected by the relation.

Data Mining

The competency ontology serves as an interface between the course outline (which has the same structure as the SCORM learning activity hierarchy for the course) and a database of risks. The database will use terminology from the competency ontology as keys and will contain records for each of the intelligence reports. The data mining process will use key words and phrases from the competency ontology to tag the reports with index terms. Attributes associated with the relationships of ontologies will be used to refine the searches based on expected subject-verb-object relationships. As shown in Figure 1, the result of the data mining will be the identification of "hot spots" in the competency ontology where new threats are being identified.

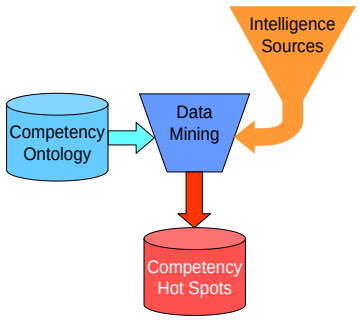

Figure 1. Data Mining for OATS

Risk Analysis

During risk analysis, each relationships in the ontology database is updated with information about the number and severity of threats associated with that relation. This process is illustrated in Figure 2.

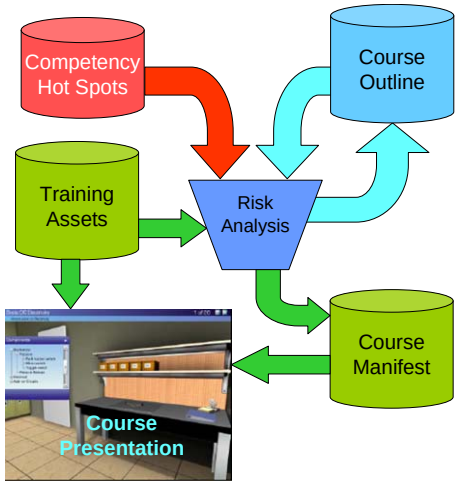

Figure 2. Risk Analysis and Course Modification

The FBI HDS competency ontology is similar to that used for training system configurations and risks (Frank, Hubal, & O'Bea, 2007). In that work, the risk data was derived from a database of vehicle accident reports. In this case, the risks will be derived from incoming intelligence reports. The accident reports provided information at various levels of abstraction about the circumstances of the accidents, so that in some cases, the only information about the vehicle involved was that it was a truck, whereas other reports were very specific about the make and model of the vehicle that caused the accident. Calculations built into the ontology were used to distribute the risk costs appropriately, so that the costs for different vehicle and environmental conditions could be compared with corresponding training vehicle and environmental conditions at multiple levels of abstraction. Similar variations in the levels of abstraction in the intelligence reports are expected in the inputs to the FBI HDS. Therefore, RTI is working on ways to process risk information based on reports received with varying levels of detail.

As with the previous application, the ontology will be used to align training system configurations with corresponding risk data as a visualization tool to help decision-makers determine where to invest in dissemination and/or courseware modification. The course outline will be annotated with information about the availability of data needed for the courseware modifications to allow cost-benefit tradeoffs.

Courseware Modification

As indicated in Figure 2, the initial focus of courseware modification is on the modification of the course manifest, which selects the appropriate assets to provide the training to the student. The outcome of the risk analysis will indicate which required assets are missing or need to be updated. If modifications are made in the assets, another cycle of risk analysis can be executed to modify the course manifest and incorporate the updated assets.

BLENDED TRAINING AT THE FBI HAZARDOUS DEVICES SCHOOL

The FBI HDS is in a unique position to implement an OATS based on its access to, and experience with, operational intelligence sources. Due to the rapidly changing threat of IEDs, the FBI HDS has an urgent need for operational adaptive training. The FBI HDS is responding to this need with the development of an OATS program for initial certification training and continuing education. Their strategy is based on four key tenets:

- Use of virtual training tools to provide vivid experiential training that puts information about new threats in a relevant context
- Incremental development of a training program that is constantly adapting to an evolving training need and has access to the streams of intelligence on that training need
- An interdisciplinary training development team that combines experience with the subject domain, the teaching and learning processes, and distributed learning technology
- Use of distributed learning technology, including the SCORM and a LMS for rapid dissemination and continuous improvement of the evolving training.

The FBI HDS has adopted the Familiarize, Acquire, Practice, and Validate training model (Helms, Frank, & Voor, 2000) to optimize the blend of live, virtual, and constructive training for their training audience.

In the Familiarize mode, the FBI HDS course uses 3-D virtual reality models and other dynamic visualization techniques to allow the student to explore and obtain prerequisite knowledge, such as equipment, tools, and terminology, to perform a task,. For example, FBI HDS training uses Familiarize mode instruction with 2-D and 3-D models to help students become familiar with the components of explosive devices.

In the Acquire mode, the student acquires knowledge of how to accomplish a task in terms of a sequence of actions to be taken, the objects (or subjects) to act on, how the objects (or subjects) react, and what tools to use to perform the actions. The FBI HDS Acquire mode training provides cues, such as search pattern arrows draped on the terrain to guide students through searching for radiation sources.

The Practice mode provides free-play for the student and, at the same time, provides a variety of training scaffolding, including hints and immediate error feedback. During Practice mode, the student receives immediate feedback when he or she makes a mistake.

In the Validate mode, all the feedback is saved to the end of the lesson and is documented in an After Action Review report. The lesson is automatically ended when the time limit is reached. This gives the training a real-time aspect that is appropriate for these critical tasks.

FBI HDS Course Overview

The FBI HDS Remote Training project is being developed to provide training to bomb squad units anywhere they have access to a computer and a secure link to the Internet. It is part of a blended training solution with a mix of live, virtual, and constructive training that combines distributed training wherever the officers are located, with residential training at the FBI HDS center in Huntsville, AL. The following paragraphs describe the training of five modules:

- Basic Electronics
- Device Identification
- Radiation Detection
- Response Planning and Operations
- Robotics Operation.

Basic Electronics

The FBI HDS Basic Electronics module uses a blend of live institutional training and virtual training for basic electronics. In the virtual training, students see the components in 3-D and configure standard circuit configurations using a virtual test bench. The student is familiarized with the components in the Basic Electronics module and is then expected to demonstrate the application of that knowledge in the validation portions of the Device Identification module.

The FBI HDS Basic Electronics module provides the knowledge needed to understand the electrical detonation of explosives. It describes the components (e.g., switches, timers, batteries, and loads) of a variety of electrically detonated explosive devices. The course uses a virtual test bench (see Figure 3) to explain the purpose of each of the components and how they are connected.

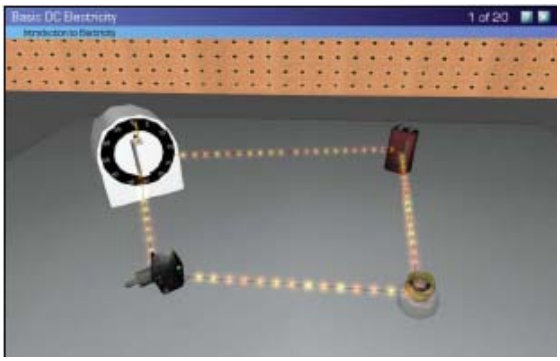

Figure 3. The Virtual Test Bench of the FBI HDS Basic Electronics Course

Device Identification

The hazardous Device Identification module is a critical element of FBI HDS training. Students must be able to recognize and classify devices either by looking at fully exposed devices or by viewing X-rays of concealed devices. The FBI HDS uses both constructive (with deactivated real devices) and virtual methods for this training. Figure 4 shows a practice training session where the student is viewing an X-ray of an explosive device and is identifying the components of the device. Students are required to identify the five key components. Consistent X-ray and photographic views are provided so that students can make the connection.

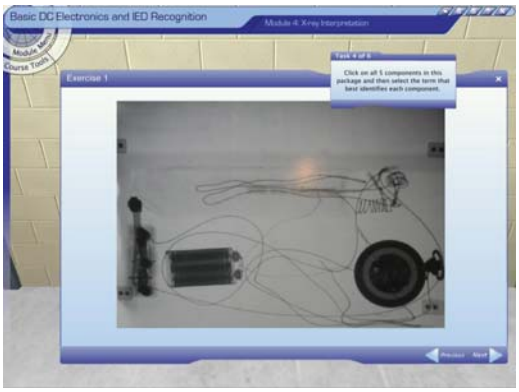

Figure 4. Device Identification in the FBI HDS Course

Radiation Detection

The FBI HDS training uses a blend of constructive and virtual training for the Radiation Detection module. To provide low-risk but realistic constructive training (as defined in Helms, Frank & Voor, 2000), a Hands-on Trainer has been developed with the same look and feel as a real radiation detector. This device is used in combination with a wireless radiation source simulator. This allows the instructor to position the source and adjust the level of simulated radiation emanating from the device. Before this constructive training is used, the students complete a virtual training session as shown in Figure 5. The virtual training can be conducted asynchronously and provides many environmental conditions and scenarios that may not be available for the constructive training.

Figure 5. Radiation Detection Training at the FBI HDS Course

Response Planning and Operations

The Response Planning and Operations module covers risk assessment and situation analysis. It provides for familiarization of and practice on search procedures for bombs and procedures for responding to bomb threats. It also covers procedures for examining and opening various containers used for bombs and detecting and avoiding booby traps.

Robotics Operation

The Robotics Operation module uses a combination of constructive computer models and simulations to train the student on the motor skills needed for the operation of robots in bomb disposal missions. It is designed to train the cognitive skills needed for using a robot to defuse a bomb. Figure 6 shows an example of the virtual world simulation included in the training module. The student can manipulate this virtual world either by using the keyboard and mouse of a personal computer or using a game controller, or by connecting the operational robot remote control to the personal computer through a USB interface.

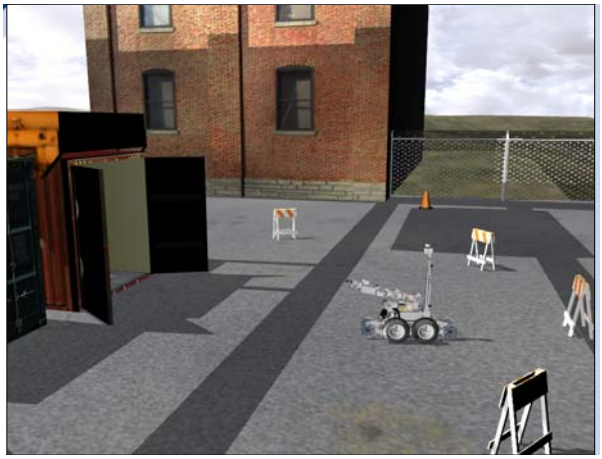

Figure 6. A Virtual Training Environment for Bomb Disarmament Using a Robot

INTEGRATING AN OATS INTO THE FBI HDS PROGRAM

We are developing strategies for incrementally upgrading the OATS's capabilities for the FBI HDS remote training. The initial focus is on adapting the device identification lessons to the emerging threats. This will allow FBI HDS instructors to ensure that training remains consistent with the current threats, even to the frequency of examples pulled from the test banks for practice and exams.

Ontology Elements

The ontology for the FBI HDS includes the following elements:

- The course outline or hierarchy of learning activities for the institutional course structure that will be continuously adapted. This outline extends

to the collection of scenarios used for the practice lessons and the comprehensive exam in the Device Identification module.

- High-level task definitions like "Defuse *device* under *conditions* to *standard*." These high-level definitions have been abstracted from task descriptions developed by the FBI and used to assess students in their institutional training. They form the basis of the ontology. As illustrated by Figure 7, we can instantiate specific tasks for assessment by choosing items from device, condition, and standards taxonomies.
- An existing taxonomy for categorizing explosive devices. The starting point for this work is the taxonomy of hazardous devices that is being taught by the FBI HDS. Each element in that hierarchy has a corresponding ontology of components and connections between components.
- High-level threat definitions that are defined in terms of relationships between the device and environment taxonomies similar to the structures shown in Figure 7.

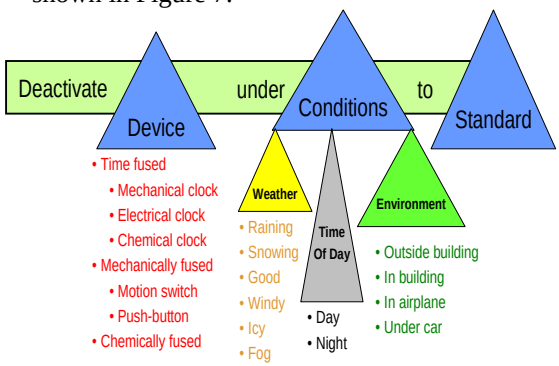

Figure 7. Example Competency Ontology

Data Mining of Notifications

The competency ontology being developed for skills related to the identification and handling of hazardous devices includes a taxonomy of hazardous devices and a taxonomy of threat locations. For this application, the database of risks will be derived from incoming intelligence reports about changing threats. Data mining will be used to build the risk database using the taxonomy of devices as the primary key and information about the location of threats as a secondary key.

FBI HDS Courseware Risk Analysis

Once the intelligence reports have been mined for device and location tags and risk metrics, the competency ontology will be augmented with information about recent incidents or discoveries, as well as information about the risks associated with those incidents or discoveries. As shown in Figure 1, the result of the data mining is an update of the competency ontology showing risk "hot spots." Attributes about the severity of the threat in the report will be included in the "hot spot" data. This data is rolled-up in the taxonomy to provide summary risk reports.

The competency ontology is then used to match risk data with the current course outline to see whether the course is aligned with the current threat, or whether there are instructional gaps (Frank, Ostyn, & Gemeinhardt, 2005). Information about available course assets linked to the competency ontology can also be checked to see what level of effort is needed to produce a new course lesson to fill identified gaps. For example, the primary assets needed for the device identification lessons are photographs of devices and information about the components. This gap analysis can be reviewed by the FBI HDS staff to decide on possible course updates to be distributed by the LMS to law enforcement agencies across the country.

FBI HDS Courseware Updates

The initial focus for automatic courseware updates is the Device Identification module. This involves determining which device photographs to use for practice and for the module's final exam.

CONCLUSIONS

- The changing threat environment calls for frequent updates to keep all types of First Responders safe and effective when protecting citizens from hazardous devices.
- The widely dispersed training audience and tight local First Responder budgets require training to be delivered to the agents wherever and whenever they can study.
- Adaptive Operational Training uses the Internet to rapidly distribute training updates to many types of First Responder agencies.
- New Semantic Web technologies, such as ontologies and data mining, show promise as tools that can automate much of the training process and reduce the cost and lag time in getting scenario-based training to the First Responders.

ACKNOWLEDGEMENTS

We wish to acknowledge the support and vision of the FBI Bomb Data Center and Hazardous Devices School instructors and management, who have seen the need for, and enabled the development of, training solutions for First Responders across the nation. We also wish to acknowledge the efforts of our partners at WILL Technology Inc. in the development of FBI HDS course materials.

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