U.S. Mining Safety Lab Uses Autodesk's 3ds max To Develop 'Virtual Reality' Training

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Mining has always been among the most dangerous occupations. Any enterprise that involves plunging hundreds of feet into the earth, breathing dust, and operating heavy machinery in total darkness obviously will have risk factors that go off the charts.

Two dramatic mining accidents recently focused the nation's attention on the hazards of mining. In July 2002, nine coal miners at the Quecreek Mine in Somerset, Pennsylvania, were trapped for three days in a flooded shaft, sometimes up to their necks in water, while TV viewers around the world watched the rescue effort. Earlier, in September 2001, 12 miners died in a methane explosion at a coal mine near Birmingham, Alabama, when they tried to rescue a trapped comrade 2,000 feet down. It was the worst American mining disaster since 1984.

While certain mining risks are impossible to change, other safety factors have consistently improved over the years, thanks to research and technology. Since peaking at 3,242 fatalities in 1907, fatality rates have steadily declined to 61 mining deaths and 14,668 injuries in 1991, and most recently to 41 deaths and 6,100 injuries in 2001. Many of the innovations that have made mining safer emerged from the federal Spokane Research Laboratory in Washington state, where 80 engineers in several project areas work to understand why mining accidents happen and to reduce the incidence of injuries. 3D design and modeling tools such as Autodesk's 3ds max™ have been instrumental in helping the Lab's engineers develop new safety innovations.

Designing 'Virtual Mines' in 3D

The Spokane Lab was created in 1951 as part of the U.S. Bureau of Mines, primarily to research rock bursts that had killed miners in northern Idaho's Silver Valley, one of the richest regions in the world for silver, lead and zinc. The Spokane Lab's territory later expanded to include most of the West, and when the Bureau of Mines was eliminated in 1996, the Lab was transferred into the National Institute for Occupational Safety and Health (NIOSH), part of the U.S. Centers for Disease Control and Prevention.

About half of the Lab is given over to laboratory space, and researchers investigate how injuries or other health hazards can be prevented in mines. One division at the lab has used 3D imaging tools to create "virtual reality" mine environments for hazard response and evacuation training. The lifelike, interactive settings are part of a basic PC software package NIOSH is completing, which can be customized by mining companies to match the layout of specific mines.

The "virtual mines," complete with hazards such as fire, floods and collapsing roofs, are gradually being incorporated into the mandatory training sessions that miners receive each year. Such an effort would have been prohibitively expensive for both the Spokane Lab and the mining companies before the arrival of 3D modeling tools and game programming engines that work effectively with a mid-range desktop PC and a standard 3D graphics card.

The Virtual Reality Mine Safety Training program is the brainchild of Tim Orr, Marc Filigenzi and Todd Ruff, engineers at the Spokane Lab with expertise in 3D modeling. The training project had its roots in early experiments with 3D that began in the early 1990s, when the Lab was still part of the Bureau of Mines, in which the Lab exported 3D AutoCAD models into structural analysis software, such as ANSYS, trying to determine the stability of underground mine openings. Then, as tools such as Autodesk's 3ds max became more sophisticated and accessible, the Lab started to think of 3D graphics in terms of mine planning - as

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another way to represent the complex innards of a mine operation.

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Since then, specialized 3D mine modeling software by providers such as Maptek (Vulcan) and GemCom has come into wide commercial use for planning and visualizing mines, and many operations use them in conjunction with AutoCAD drawings.

From Mine Planning to Safety Training

After the Spokane Lab was folded into NIOSH in 1996, the Lab began to hear requests for more and better training programs, and Orr and his colleagues realized that the same 3D tools they were using for mine planning and visualization could be used to create lifelike training simulations. Miners would go into an interactive environment elaborately constructed to resemble their own mine, spot potential hazards, respond to accidents and find their way out safely through darkness, smoke or floodwater. Two developments were instrumental in expanding "virtual reality" (VR) systems to mine training: PC-based 3D programming tools and new, interactive 3D computer games.

"The VR systems we were looking at were made for really high-end computers with custom graphics cards and workstations, and the software itself was also expensive," Orr said. "But when first-person 'shooter' games such as Quake and Unreal came out in the 1990s, their VR technology ran on a basic PC, and you just needed a reasonably nice graphics card. We realized that the game environments were very similar to the networks of underground tunnels that we work with. There were also a lot of hazards in these games - if the bad guys didn't get you, things could blow up. These only had to be modified slightly to be usable for our training."

Importantly, the game companies invited third-party programmers - in fact, anyone who wanted - to manipulate their programming code and create new game material. Chief among these was the state-of-the-art Unreal Engine, a widely used game program made by Epic Games, which released a CAD-like editor for its game and encouraged programmers to dig in.

"They realized that most of these games have about 30 hours of material and that kids could exhaust them in a single weekend," Orr said. "So Epic decided they could greatly improve their shelf life by allowing people to edit the game. They made it compatible with Autodesk's format, which allowed us to import 3D mine drawings into the game engine as DXF files." (DXF stands for Drawing eXchange Format, Autodesk's protocol for exchanging vector-based graphics files among different CAD applications.)

Rocket Launcher Out, Fire Extinguisher In

Orr said being able to "borrow" existing functionality from game engines that are already filled with content makes VR design much easier for someone like him; his background is in mechanical engineering, not 3D programming. "For example, we took a rocket launcher from the game and converted it to a fire extinguisher," he said. "Instead of blowing things up, you can put out fires. We

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Engineer
Spokane Research Lab

could drag-and-drop characters, import textures, objects, machinery, or go out with a digital camera and bring in photos of mine floors, walls and roofs to make it look realistic. We just created a whole world."

Autodesk's 3ds max is an important tool in that effort, Orr said. "Everything we do goes through 3ds max at one point or another," Orr said. "Polishing imported mine drawings, or adding textures, or building 3D models. I never really feel like I've grasped more than 5 percent of what it can do."

Orr's team also used 3D imaging accessories such as Autodesk's character studio® to create human figures for the mine environment, and a photogrammetry program called PhotoModeler Pro, made by Eos Systems. "We did a 3D version of myself dressed as a miner, using photos taken from several different angles. The software then triangulates them based on a common position, such as my nose, and creates a 3D mesh with X-Y-Z coordinates. We did the same thing for a model of my Isuzu Trooper. Then we can enhance the models in 3ds max, and in the end we have photo-realistic, low-polygon 3D models that work nicely."

The Spokane Lab's VR miner characters aren't all clones of Tim Orr, though. Lab designer Ian May recently created a female miner for the simulation using Paul Steed's book, "Modeling a Character in 3ds max." "The complaint was, how come we always have to look at your face?" Orr said, laughing.

Assembling a Basic VR Toolkit

The Lab's strategy is to build a standard library of Virtual Reality tools and tutorials on how to use them, then make the VR package available to mining companies that would adapt their own scenarios, tailored to their mines' unique features. "Our kit will have generic mining equipment that they can use to populate the environment, mixing it with their own photos and 3D data," Orr said. "Their miners would walk around and recognize it as their own work area."

NIOSH is Beta-testing a preliminary version of the VR software at the Twentymile Coal Company's Foidel Creek Mine in Western Colorado, where the CD has been installed in a training room at a local community college used by several mining companies. The Spokane Lab is also doing a pilot project at the Stillwater Mine, not far away in Nye, Montana, exchanging 3D data with programmers there to custom-build a VR environment. Like all mine operations, these companies must give employees 40 hours of mandatory training before they can enter a mine, and thereafter provide eight hours of refresher training each year.

Under industry regulations, a section of that training must focus on evacuation procedures, so Orr's team developed a one-hour VR module on "escape training." They took advantage of a gaming feature that allows as many as 32 people to interact together in the mine environment, sitting at different computers, although groups of four to eight are more practical.

"All of these people are trying to escape from the same fire, and they can decide if they're going to follow each other," Orr said. "We sort of drop them into an unfamiliar place and they have to wander around and get their bearings. We've created landmarks that they must look for, to navigate whether they're heading out or moving further into the mine. Then their visibility is limited by smoke, and they can't see the other trainees' characters or the landmarks. They have to follow an established procedure: find the mine phone, gather at a big transformer where they can find a breathing apparatus, then move toward fresh air. Sometimes we can throw curves at them, like secondary explosions or roof falls. It becomes a kind of maze."

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Pennsylvania Flood's Lessons

In a mining accident, communicating details to the surface is critical. Orr pointed out that in the flood that trapped miners in Pennsylvania's Quecreek Mine for several days last summer, the crew that became caught alerted the surface when the water hit, which allowed another group to escape before the flood pinned them as well. "That call probably saved their lives," he said. "After that accident, we started building more into our VR flood scenarios - water zones in the mine, and objects that become buoyant if you hit water."

Orr said the VR scenarios the Lab has developed are applicable to other industries beyond mining. "Especially after what we saw on September 11th, we think the training could be valuable for any big facility that has a complicated escape scenario," he said. "A building where smoke could change visibility, where knowing the right routes is essential such as chemical plants, large warehouses and factories."

When the Spokane Lab ran in-house tests to see if repeated experience in the mine environment would improve the escape times of participants, the results were promising. "We got about a 37 percent decrease in the amount of time it takes to escape the training scenario," Orr said. "So there's a benefit in the virtual world, and I think that will translate into the real world. It shows they're spending less time making decisions, and that's the key statistic. It shows that maybe we can reduce the number of deaths."

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The NIOSH Spokane Research Laboratory's Autodesk solutions were implemented and supported by PacifiCAD, Inc. of Spokane, Washington. Call 800.722.2621 for information or visit www.pacificad.com.

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