Scenes such as this explosion in Iraq have been typical in recent wars as insurgents and terrorists create homemade explosives that are often deployed as roadside improvised explosive devices (IEDs). Explosive Ordnance Disposal (EOD) technicians in the U.S. Air Force, Army, Marine Corps, and Navy tackle the tough job of detecting, rendering harmless, and disposing of a wide range of explosive materials. Los Alamos teaches EOD techs how to save lives by recognizing homemade bomb labs and the raw ingredients commonly used to make IEDs and other bombs. EOD techs also learn safety measures, get hands-on experience synthesizing the materials, and study the sensitivity and performance characteristics of those materials. The Los Alamos National Laboratory Advanced Homemade Explosives Course uses science and hands-on training to keep EOD techs out of the "hurt locker." (Photo: U.S. Army)

THE HURT-LOCKER SCHOOL

Los Alamos's Advanced Homemade Explosives Course puts world-class science to work keeping military Explosive Ordnance Disposal techs safe.

Under an exhaust hood shielded by safety glass in a research laboratory, a U.S. Marine Corps sergeant named Alvin puts three white crystals, each the size of a sea-salt grain, into a piece of foil crimped like a cupcake liner. It's Day 2 of the Los Alamos National Laboratory Advanced Homemade Explosives Course. Two other marines and an airman, all Explosive Ordnance Disposal (EOD) technicians, crowd around. Alvin clicks-on a disposable gas lighter and waves the flame back and forth below the foil for a few seconds…

Bang!

A bright blue flame flashes off the sample. Everybody jumps, except instructor Virginia Manner, a Los Alamos staff scientist in the High Explosives Science and Technology group. Manner runs the course with co-leader Margo Greenfield of the Shock and Detonation Physics group. None of the EOD techs—all experienced with explosives—expected this batch to go off like that.

"Whoa!" says Devin, another marine sergeant. "I wasn't ready for that!"

"That was freaking *awesome*!" Alvin says.

The energy in the room ratchets up several notches. So does the techs' respect for this powdery homemade explosive that behaves similarly to a conventional high explosive (pentaerythritol tetranitrate) that Laboratory scientists have been researching to better understand its performance and sensitivity characteristics.

> **If you've seen the movie The Hurt Locker, which many techs say exaggerated their work for the sake of drama, you have some sense of how tough that job is.**

"This type of explosive material has interesting properties," Manner tells the group. "You may be tricked into thinking it is safe to handle." She pauses slightly for emphasis: "It isn't."

That's a lesson crafted particularly for the 20 or so EOD techs attending the course designed for them by Los Alamos. EOD techs have a tough job. Their lives—and others' lives, too—depend on how much they know. From all branches of the service, these techs routinely get the call to dismantle homemade explosives (HMEs) along dusty roads, for instance, or neutralize HME factories in war zones. If you've seen the movie *The Hurt Locker* (which many EOD techs say exaggerated their work for the sake of drama), you have some sense of how tough that job is.

EOD techs learn to test the sensitivity of a small quantity of an unknown explosive material by hitting it with a hammer in progressively harder strikes, eventually producing a flash and a pop. (Photo: Los Alamos)

Hammer Time

The label "explosives" covers a wide range of substances that are characterized by liberating energy and producing heat under a stimulus, "like an impact or spark," which sets them off, according to a standard text in the field, *The Chemistry of Powder & Explosives*. The EOD techs at the Los Alamos course are experimenting with the homemade kind, defined loosely as any improvised concoction of readily available material that can blow up, often in an improvised explosive device (IED). One dangerous task facing an EOD tech is determining whether a material—a white powder, for example—is, in fact, an explosive.

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Manner started this lesson by guiding the team through preparing a batch of improvised homemade explosive using common off-the-shelf ingredients that you might find at a local hardware or grocery store, so the techs can see how it's made and how it reacts to a stimulus.

What will set it off?

The team works in Manner's lab, a narrow room with floor-to-ceiling steel cabinets, glass-fronted ventilated hood areas for handling chemicals, a sink, plenty of counter space, and a pull-chain shower for an emergency rinse. An army captain, currently on assignment at Los Alamos for a year as a Department of Defense (DoD) liaison, observes from the side. Wearing safety glasses, ear plugs, and white lab coats over their camouflage uniform pants, the EOD techs joke with Manner and then focus on mixing the improvised explosive. Alvin reads the printed instructions aloud while the others measure the precursors into various beakers. A Teflon-coated piece of steel the size and shape of a vitamin pill agitates the mixture on a magnet-driven stir-plate behind safety glass. Next comes the slow process of precipitating the explosive to form a sludge that will dry into a powder.

After rinsing the explosive, Manner nudges it out of a funnel. Dampness makes the explosive relatively safe to handle. Now Richard, an EOD tech in the Air Force, picks up a pair of hammers, sets the head of one over a few grains of the explosive on a small anvil, and starts tapping with the other hammer: once gently, once hard, and once really hard. Nothing happens. Too much water. Eventually, a swift strike triggers a pop.

> **We want EOD techs to have respect for the explosives but not be so afraid they can't walk into an HME lab.**

The "Aha" Moment

The techs talk about "getting left of the boom," which means working before the bomb goes off. "Right of the boom" means it's already blown up. The Los Alamos course is all about working on that left side, *safely*. To that end, every six weeks for five days, about 24 techs come from the Air Force,

Marines, and Navy to learn more about how the bad guys whip up explosives in makeshift labs.

"Currently, we're enhancing the EOD techs' understanding of HME threats and the labs that they might encounter when deployed," Manner says. "The course teaches them how to safely go through a lab, for instance, and understand what's being made and how to handle it."

Everything the EOD techs learn this week will apply to combat. They can safely conduct a hammer test with common tools in a Humvee and a flame test with a pocket lighter to determine the sensitivity of a questionable material. They are also learning how to identify explosive ingredients, how to desensitize explosives (for example, by spraying them with a special liquid), and how to transport them.

The course also aims to develop critical thinking skills. Later, when the techs find themselves in a hostile situation, "they can apply logical thought processes and critical reasoning because they understand the fundamentals behind how the explosives work," explains Clinton, an army captain and a qualified EOD instructor who once ran a team of instructors. Clinton was also a DoD liaison at Los Alamos.

"This course doesn't pretend to be tactical," he says. "It's very cerebral, very academic in getting across the basic chemistry and physics principles to explain why things work. I see a lot of connections being made by the students. The first two days are a deep dive into what an explosion is at a fundamental level. The EOD techs understand it in an intuitive sense. They get how all these things work, but understanding why—that's the 'aha' moment."

The techs explore simulated labs in a mock village tucked into one of the Laboratory's remote canyons.

Days 1 through 3 of the course provide an overview of general HME characteristics, the hazards, and related safety precautions. Forty-five-minute lectures are balanced by two-hour labs, when the EOD techs formulate and test explosives. The lab ratio is one instructor to four or five students, with lots of interaction among them.

"The labs show them how, starting from very simple precursors, we make this thing that's very dangerous," Manner says. By understanding its characteristics, they can safely handle it. "We want them to have respect for the explosives but not be so afraid they can't walk into an HME lab."

Later in the week, the students work with unidentified explosives on the outdoor range. By relying on high-speed video of the explosions, detection equipment, and observations of effects such as the color of smoke, the EOD techs identify the materials. On another day, the techs explore simulated labs

Los Alamos explosives scientist Bryce Tappan of the High Explosives Science and Technology group demonstrates the flame test for a class of EOD techs. The class had just made a small batch of an explosive often used in improvised detonators. Exposing a few grams to flame and observing how the substance ignites helps the techs identify it and determine its sensitivity. (Photo: Los Alamos)

An Afghan border police commander stands by as two EOD techs photograph a pressure plate. Pressure plate components are used in conjunction with improvised explosive devices. (Photo: U.S. Army)

in a mock village tucked into one of the Laboratory's remote canyons. In ramshackle huts representing scenarios around the world where EOD techs might find explosives, students investigate rough chemistry labs containing beakers, burners, and unlabeled materials—a white powder, a jar of liquid, and so on. Working in groups in this realistic setting, the students must find, identify, and analyze the materials, then handle them appropriately.

"Many of the starting materials are used for legitimate industrial applications, but they can also be used to make homemade explosives," Greenfield explains. "We teach them what to watch for. When they walk into a lab in theater, they might not know, without going through the course, how to safely deal with those materials."

Flexible Course Puts Safety First

Becky Olinger, associate director of the Los Alamos National Laboratory's Explosives Center and program manager of the Los Alamos Collaboration for Explosives Detection, played a key role in launching the HME course. In 2009, the Lab first offered an HME situational awareness course for the DoD; lectures focused on awareness of HME types, "sights and smells," and equipment used to make HMEs. It also included "shot demos" of explosions and mock village search scenarios. This course lacked hands-on lab work in synthesizing explosives. That important educational component was added to create the advanced course.

> **The EOD techs want to know, can the enemy do this? Is it possible? Would it work?**

"Due to several previous HME training accidents that occurred with private companies who did not understand the hazards and safety requirements associated with explosives, the DoD asked Los Alamos to take the lead on the advanced HME training course," Olinger says. "These other courses offered by private companies who have had accidents have been 'banned' by the DoD. They called us and said, 'You have a record of solid safety practices, and we trust you'll come up with the safe training we need.' So we ended up taking it over."

Los Alamos began offering the advanced course in June 2009. The July 2015 course was the 23rd session.

"An EOD tech put together the initial curriculum," Greenfield says. "He knew the threats, and he said, 'We want this, that, and the other.' " She says Los Alamos is flexible enough to adapt the course on the fly to address new, previously unknown threats. "We're flexible."

The course has flexed already. Intelligence analysts contribute to the course's content, as do DoD liaisons and students in the course who were recently deployed as EOD techs in theater. As one army captain put it, this adaptability is "a huge strength" of the Lab course. "It's incredibly dynamic," he says. "We have our finger on the pulse of the intelligence."

> **The course is a rare and valuable opportunity to work directly with the materials in a safe environment.**

Manner recalls a recent example: "We had been talking about a homemade explosive that we believe could decompose in the presence of humidity, which could create a dangerous situation if it decomposed quickly and violently," she says. "During a lecture, we talked about how it would form ammonia gas when it decomposes, so that smell, coupled to the presence of that particular HME, would be indicative of a dangerous situation. Several students said they had encountered that exact HME in Afghanistan and smelled ammonia. Now they know it was in the process of what could become a potentially violent decomposition."

An EOD tech participates in the Lab's Advanced Homemade Explosives Course. Inside a structure in the Lab's mock Afghan village, course instructors stage materials and equipment to simulate an explosives laboratory. Students must safely identify the bomb ingredients. (Photo: Los Alamos)

Manner says the curriculum also incorporates pictures and videos that EOD techs provide from war zones. In all these cases, the EOD techs "provide validation for us," she continues, "because they either reinforce the subject matter we teach or confirm it through personal experiences. Or sometimes they even tell us that what we are teaching needs to be updated."

Hands-On Learning "Stays with You Longer"

The HME course would not be possible without the contributions of the many scientists, engineers, and technicians in multiple divisions throughout the Laboratory. The diverse team of practicing bench scientists who teach the course at Los Alamos distinguishes it from other courses—a fact not lost on these students. The Lab currently has more than 20 instructors with expertise in explosives.

A marine master sergeant vouched for the instructors' top-rank expertise: "You can't find smarter people. They're not just regurgitating what they remember. They're easy to understand, and the course really fits our level."

"Having true subject-matter experts in the field means there isn't a question they can't answer," says marine staff sergeant Tom, an EOD tech who was deployed in Afghanistan and a veteran of other explosives courses. "That's different from several previous courses I've taken. They're giving us information all the way from basic theories and the properties of explosives to how to produce them in the lab. Then we go to the range and see if they work."

For Tom, the hands-on laboratory instruction in the Los Alamos course is a rare and valuable opportunity to work directly with the materials in a safe environment. "You can

A coalition trooper in Afghanistan uncovers a Taliban cache of explosive materials, including ammonium nitrate and detonation triggers, that can be used to synthesize homemade explosives. In caches and ad hoc bomb labs, EOD techs must determine the nature of materials they find and safely dispose of them. (Photo: Department of Defense)

A female member of the 630th Explosive Ordnance Disposal Company prepares to clear a known explosives cache site in Afghanistan. Many female EODs participate in Los Alamos's Advanced Homemade Explosives Course. *(Photo: U.S. Army)*

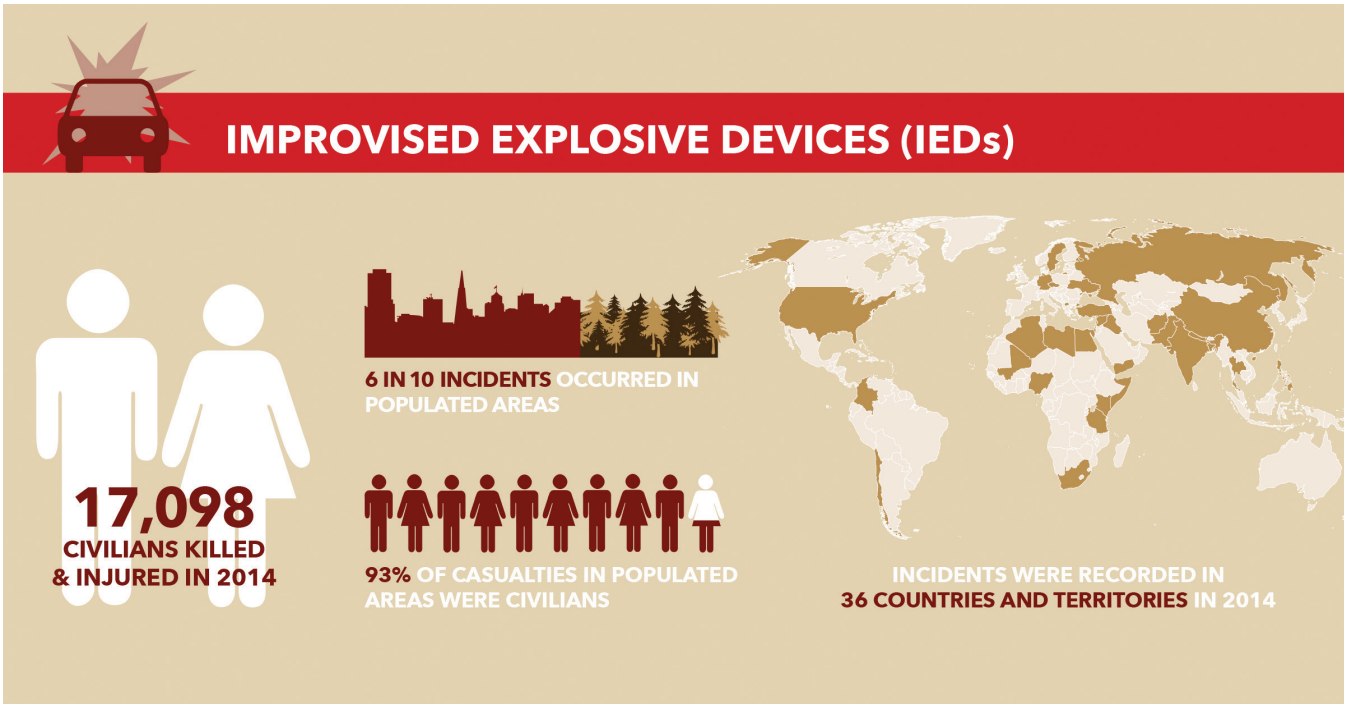
look at pictures all day, but when you learn in the lab like this and you make the explosive yourself, you have the sights and smells, too, and it stays with you longer."

Staff sergeant Tom also appreciates the ability to quiz practicing scientists: "I came in with questions about detonation speed propagating from one explosion to another, from the primary to the booster to the main charge. I can go to reference books for answers, but they require a level of knowledge that I don't have. It's nice to have someone who can translate that for you."

Army captain Clinton joked about EOD techs sitting around their hotel rooms at night thinking up tough questions to ask their scientist-teachers the next day. Good luck. He explains: "These scientists have done the work with these explosives—and they did it yesterday." Such intimacy with the material means they can provide rich answers to students' questions. "The EOD techs want to know, can the enemy do this? Is it possible? Would it work? A vast majority of the time, the instructors can give them a definitive answer because they have tested that same thing."

The Adrenaline Advantage

Some of the HME course students have forged their skills on the battlegrounds of Iraq and Afghanistan. Some are just starting their careers. Others have risen to supervisory and administrative positions. Although all the students in the July class were men, women also serve as EOD techs and often take the course. Students' education levels range from high



Explosive violence harm caused by IEDs in 2014. *(Infographic courtesy of Action on Armed Violence)*

school to graduate school, but everyone has been through military training on explosives, including the Naval School's Explosive Ordnance Disposal course, which techs from every service branch attend. They all need to know more about how to combat the ever-varied and unpredictable threats of HMEs.

> **They go through demanding testing to ensure they can handle high-stress situations while dismantling a bomb.**

The instructors are unanimous in their appreciation of the students' knowledge. "They're all smart and all inquisitive," Manner says. Greenfield adds, "It's a very rigorous process to become an EOD tech. They go through demanding testing to ensure they can handle high-stress situations while dismantling a bomb."

Clinton agrees: "The EOD tech is a higher caliber of service member. It takes good test scores and passing stringent physical requirements to get into the Naval School's EOD course, and a lot of people wash out. These guys are confident and like the excitement. That's true for anyone in the service, but it takes an extra leap to be an EOD tech and to approach these dangers."

"They're eager to learn and get the practical application," he continues, "because every bit of training, every bit of knowledge is going to keep them safer."

"I'm definitely grateful to be here," Tom says, noting he and his comrades-in-arms will benefit from their study time at Los Alamos. "We'll take it back and apply it to operations."

For Manner, that practicality makes the course worthwhile. "Research can sometimes be isolated from current real-world applications," she says. "During this one week every six weeks, we get to do something real, when we're actually helping somebody. It's the most valuable thing I've ever done."

Greenfield agrees: "All the instructors feel that way, and that's why it's so successful. We know we're increasing the EOD techs' overall safety. We're using world-class science to save lives on today's battlefields."

~Charles C. Poling

Virginia Manner (left) of the High Explosives Science and Technology group and Margo Greenfield (right) of the Shock and Detonation Physics group co-lead the Los Alamos National Laboratory Advanced Homemade Explosives Course. Like all the instructors, Manner and Greenfield conduct research in explosives science, providing a level of expertise that students cite as a distinguishing trait of the Laboratory's course. (Photo: Los Alamos)

For more on the Advanced Homemade Explosives Course: *youtube.com/watch?v=GEnrLviSeBE*