NEED TO KNOW
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UAVs Take Flight Over Idaho

The plane banked and turned over the shimmering desert as the ground crew squinted up intently, silently watching every wing tilt. It seemed to pick up speed as it approached the cracked and weed-encroached runway but perhaps it was just the perspective from a breathless bystander. No landing gear lowered from its belly as it neared, and no warning cries came from the crew. It landed hard into the wind, skidding across the tarmac before coming to rest quietly just at the edge of the sand and sagebrush. No pilot emerged from the cockpit. One crew member approached the plane, picked it up and carried it back to the command center, already crowded with computers and crew.

This flight was just one of hundreds that INEEL's unmanned aerial vehicle team flies during operations of its several research and development projects.

Unmanned aerial vehicles, or UAVs in the parlance of the experts, look somewhat like the hobby planes flown by aviation aficionados worldwide. But these UAVs, explained project manager Scott Bauer, have a special purpose.

"It's the mission that makes the difference," said Bauer, sounding like the National Security Division employee that he is. "We're working with DARPA (Defense Advanced Research Projects Agency, see sidebar) Future Combat Systems Communications program to prove that small, low-cost UAVs can carry the payload and perform a potential future application."

The UAVs used by Bauer and his team are not quite off-the-shelf systems. They include sophisticated avionics that unleash the birds from constraining RF controls to roam the skies for hours, on predetermined flight paths. But before the military risks soldiers and battles on the reliability of the relatively tiny planes, Bauer and team members Mark McKay, Matt Anderson and Jodie Boyce are out on the Idaho National Guard Orchard Training Area, launching, flying and landing plane after plane.

INEEL Specialty

Many groups are involved in the UAV arena, from cutting-edge airframe and avionics designers to various branches of the military. So why is the INEEL not only conducting R&D projects for DARPA but also beginning

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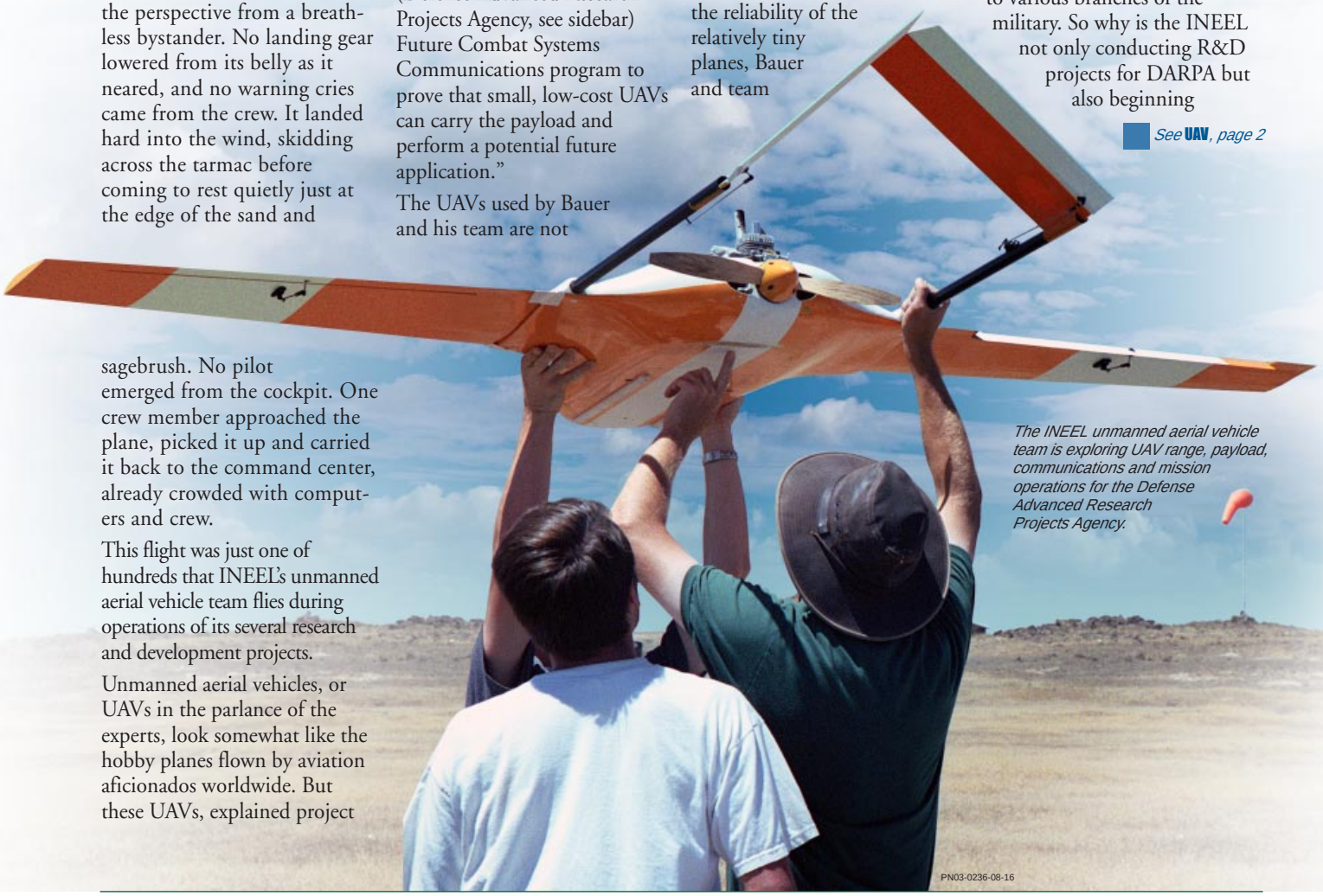

The INEEL unmanned aerial vehicle team is exploring UAV range, payload, communications and mission operations for the Defense Advanced Research Projects Agency.

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UAV *(continued from page 1)*

construction activities to build its own UAV airfield?

"We are focused on small, low-cost, disposable planes, the under-50-pound class," said Bauer. "We think that's where the greatest cost to benefit will be for UAVs in the future. We take the airframes and payloads that industry has developed, integrate the components, and independently and objectively prove if they can perform the missions of our customers. That's specifically what we are doing for DARPA in the FCS Communications project."

The recent conflicts in Iraq and Afghanistan saw a surge in specialized UAV missions, using larger, advanced and more expensive models such as the Predator and Global Hawk. As avionics and fabrication methods become less expensive, a new role is emerging for small, low-cost UAVs that brings new possibilities for communications, sensory and intelligence gathering to the ground warfighter.

And that's where INEEL expertise comes in. Autonomous flight – where the UAV is flown though computer programs and sensors rather than pilot-operated line-of-sight RF signals – is comparatively new, particularly using the sophisticated yet low-cost avionics such as Piccolo (Cloud Cap Technologies) that Bauer and the team have installed. In what is believed to be a first-ever event, in early July the team autonomously flew five UAVs from a single ground station and operator within the same two-kilometer airspace. This feat speaks to the level of autonomy that the new low-cost systems are providing.

"If we can do five, why not ten?" said Bauer. Their goal is not setting a Guinness World Record, but increasing the ability of the small planes – which can carry only small payloads and are vulnerable to mishap – to complete their assigned missions.


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The INEEL team, collaborators and summer interns (from left to right) Mark McKay, Keith Brock (Advanced Ceramics Research), Jodie Boyce, Kendall Fowkes (BYU), Reed Christiansen (BYU), Scott Bauer and Matt Anderson (top photo). Scott Bauer makes a final adjustment prior to flight (middle photo). The INEEL team uses sophisticated avionics to autonomously control the UAVs (bottom photo).

Bauer describes the potential for complex assignments with multiple UAVs carrying out a collaborative task. He said this would require self-adjusting among the fleet. If one fails, is reassigned or crashes, the remainder must still carry on.

Planes do crash. Everyone on the team had his favorite phrase. *Takeoff is optional; landing is mandatory. It's not a matter of if, but when.* But the UAV team minimizes the risk by running each operation as thoroughly as if the small planes were manned. Their Flight Ops Checklist is followed for every flight. Their procedures are "clear, concise and consistent."

Bauer knows that the more experimental the airframe,

Continued top of next page


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avionics or payload, the greater the risk. But he also knows that if you don't fly, and don't do the missions, the technology won't mature. The team gets its greatest insight by putting the research to practice.

The UAV team is conducting some experimental research of its own. According to Bauer, communications, power and propulsion are the three limiting issues confronting future abilities of UAVs. Funded through INEEL's Laboratory Directed Research and Development program, the INEEL team is targeting commercial wireless communications for research and civilian efforts. They are using cell phones to fly a highly autonomous "bird" or to augment cellular coverage.

In a test earlier this year, they used a cellular CDMA 1x connection through the Internet, to an intranet, and controlled a UAV flying in Idaho from a remote location.

"Everyone has talked about using cellular, but we put it into practice," said Bauer. "Throughput and reliability will only get better as cellular infrastructure improves."

The INEEL knows the significance of cellular infrastructure, having just this year – in partnership with Bechtel Telecommunications – established the Wireless Testbed. (See *Need to Know*, April 2003) Bechtel selected the INEEL's 890-square-mile site, in part, for its relatively free RF space. Yet its National Telecommunications Information and Administration test station status allows the INEEL to transmit at all but a few frequencies. These same attributes make it an ideal location for a UAV airfield. Add to that extremes in temperatures, winds, miles of rough terrain and a concentration of experts and applications, and you have all the necessary ingredients to field test robust systems for the military.

Mobile, Scientific Platforms

While Jerry Harbour recognizes the importance the military plays in UAV technology development, he also sees enormous potential for myriad peacetime scientific applications. Harbour is the acting manager for the Human, Robotic and Remote Systems organization, home to UAV team members McKay and Anderson and hotbed for much of the INEEL's robotics work.

"So much in science research is gathering of data, and collecting good data has been expensive," said Harbour. "UAVs today are smaller, cheaper and can be loaded with powerful sensors. When you add a long loiter time, you have a mobile scientific platform, perfect for hundreds of scientific applications."

Loiter time is the ability to stay aloft in an area. Some UAVs, even small, inexpensive ones, can circle a site for hours. Studies conducted in remote or dangerous locales – such as when assessing pollutant effects on delicate coral reefs, elephant migrations across the African veldt or awakening volcanoes on Pacific atolls – are all ideal applications for UAVs.

"You can't do these things with satellites," said Harbour. "They flash by and are gone. Manned aircraft is very expensive and sometimes dangerous. UAVs are perfect."

According to Harbour, surveillance by UAV could help monitor those environments that are subject to slow onset or creeping disasters that are not easily discernable to the naked eye. Harbour envisions combining UAV platforms with the INEEL's award winning Change Detection System (see *Need to Know*, August 2003) to create a powerful tool to detect almost imperceptible changes in a landscape.

Closer to home, Harbour and his robotics experts are working to apply UAV technology at the INEEL on such applications as remote environmental monitoring to range fire observations.

"It's not the UAV that's so great," said Harbour. "It's what it can do."

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Simultaneous Flight of Five Autonomous Unmanned Aerial Vehicles Makes History

In early July, the INEEL's Autonomous Unmanned Aerial Vehicle (AUAV) flight team simultaneously deployed a fleet of small autonomous planes, from a common ground station, as a proof of concept for the Defense Advanced Research Projects Agency. DARPA and the INEEL are fielding multi-agent AUAVs to broaden missions in ad-hoc self-healing mobile network communications.

"These AUAVs could replace a manned aircraft in situations not suited for a pilot if we can prove the mission, reliability and performance," said Scott Bauer, INEEL AUAV project manager. "We want to explore UAV range, payloads, communications, mission operations and the integration of intelligent features."

In the July exercise, a single pilot was used to launch and recover each vehicle while a single command and control ground operator and RF telemetry laptop link provided health status monitoring and course alteration. The demonstration builds a case and foundation for future multi-agent autonomous UAV work. The project targets the capability of small crews to manage multiple planes in congested airspace. The basic equipment used was comparatively low cost, small footprint, and heavily reliant on air vehicle autonomy. The work was performed at the Idaho Army National Guard Orchard Training Area near Boise, Idaho.

"Another important aspect of the demonstration is the fact that one 'pilot' flew five UAVs simultaneously," said Dr. Jerry Harbour, of the INEEL Human and Intelligent Systems Department. "From a psychological standpoint, this places a significant workload on the pilot. As we work with the military on these types of demonstrations, it's critical that we learn more about the human element in UAV flight. Indeed, we may find the biggest challenge is at the manned/unmanned interface or how flying robots and humans can best interact in order to accomplish a specific mission."

Additional work is planned by the INEEL with a higher degree of autonomy, communications and vehicle intelligence while flying specific missions. This achievement highlights the engineering, integration and field operation expertise of the INEEL crew and autopilot avionics. The autonomous autopilot partner sharing this achievement with the flight crew is Cloud Cap Technology, Hood River, Ore.

*Tim Roney, Keith Daum and Gary Gresham are researching various technologies to detect smuggled bulk currency.**

Follow the Money –

Research into detecting smuggled currency

Who smuggles money? Evidence from the U.S. Bureau of Customs and Border Protection points to drug traffickers, arms dealers and terrorists. Smuggled outbound currency is associated with a variety of illegal activities from tax evasion to bombings. The CBP wants smuggling stopped to disrupt the flow of money that greases the palms of terrorists and bankrolls planeloads of drugs. And INEEL scientists are helping them stop it. For more than a dozen years, INEEL researchers have been investigating methods to help catch those smugglers.

In October 1996, a report in the "Federal Reserve Bulletin" estimated that between $200 billion and $250 billion – almost two-thirds of all U.S. currency – was out of the country. The authors predicted that the amount was growing. And then, as now, experts held that at least some of the currency moving out of the country was being used for illegal activities.

Dogs have long been the cornerstones of CBP counter-smuggling efforts and have an enviable success rate. Still, several years ago, the agency decided to expand its detection capabilities.

"CBP was looking for a method to supplement its existing program," said Keith Daum, principal investigator for the INEEL's currency detection research. "Technology, such as a chemical sensor, adds another opportunity to detect currency. The more chances you have to find contraband, the more likely you will find it." Not everyone thought it was a good idea. Another researcher even suggested the perfect instrument. "Get a box," he said, "and put a dog inside."

Ion Mobility Spectrometry

INEEL chemists wanted to exploit one of the same analytical methods to detect currency that Customs inspectors already employed to detect drugs – ion mobility spectrometry. They didn't want to add another tool to the already burdened inspectors. But could they get IMS to detect the vapors from dollars?

It's a tough problem, according to chemist Gary Gresham. The INEEL researchers investigated inks and papers used in currency and found a consistent signature among different denominations. Gresham noted the changes in the vapor signature as the money aged, and Daum used this data to develop a method to detect money using handheld IMS technology.

This successful early research caught the attention of Idaho Sen. Larry Craig, who supported a bill to fund additional needed work on currency detection.

"When I heard about these efforts, I knew it was another case of INEEL researchers working to build a better – and more consistently reliable – mouse-trap," said Craig. "The work is important and sorely needed, but the visibility of it was not very high at the time. I knew that additional funds would keep the momentum going and, happily, we were successful in securing those funds."

"We have some good concepts here," said Daum, "and we need to fully explore not only improvements to the IMS technology but also other alternatives and approaches to detection. The senator really went to bat for us and we want this work to make a difference. When smuggled money leaves the country, it is often associated with drugs, arms and explosives. We can disrupt this cycle."

To increase IMS technology effectiveness, Daum is working

with INEEL chemist Mason Harrup (See *Need to Know*, October 2002). Harrup is developing a membrane for the IMS to filter out conflicting information.

Even while Daum and Gresham continue investigating vapor-based currency detection, the INEEL researchers are also looking into other bulk detection methods, including infrared detectors and Raman-type probes. Team member and physicist Tim Roney is evaluating radiation-based, electromagnetic-based and acoustic/ultrasonic-based approaches. The radiation-based methods, such as radiographic and tomographic imaging, could be used in situations where contraband is suspected in a container. Electromagnetic methods could include radio frequency stimulation of passive antennas, eddy currents, or optical and infrared techniques.

Roney's goal is to expand inspection capability without increasing inspection time or demands on the inspector. He believes it may be possible to modify existing systems, such as an X-ray inspection system, to provide additional detection capabilities.

U.S. Bureau of Customs and Border Protection agents vigilantly defend our borders and our citizens. INEEL researchers Daum, Gresham, Harrup and Roney are working hard to deliver scientific instrumentation to help make their job easier.

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Senator Lary Craig, shown here with Tim Roney and Keith Daum, was instrumental in securing funding for the currency detection project.


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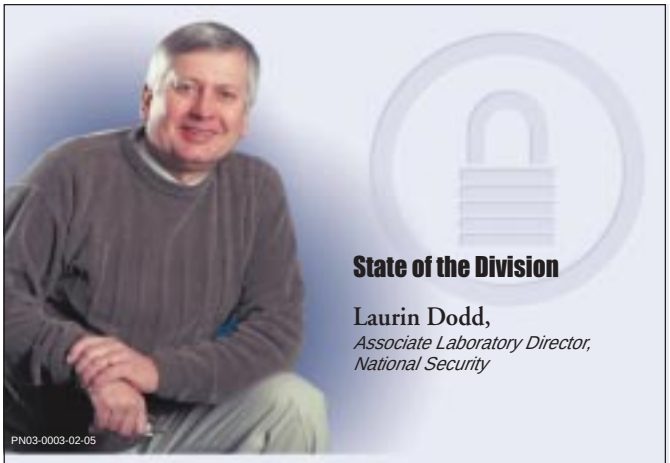
** Safety goggles are not required in this portion of the laboratory.*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State of the Division

Laurin Dodd,
Associate Laboratory Director, National Security

As the first anniversary of the Department of Homeland Security approaches, it is notable that the three technologies highlighted in this issue address homeland security needs in very different spectrums. Together, they highlight both the breadth of our contributions to homeland security, and the ability to test and demonstrate a range of technologies on our 'critical infrastructure test range.'

Smuggling of currency across our national borders contributes to terrorism and illicit drug trafficking. Scientists at the INEEL, longtime leaders in the development and use of ion mass spectrometry, are making significant contributions to the U.S. Bureau of Customs and Border Protection in developing and deploying advanced technologies to reduce currency smuggling. We are grateful to Sen. Larry Craig for his interest in this program and his support in helping us to make a difference.

The INEEL is an engineering laboratory. Our staff takes considerable pride in designing, building, testing and deploying engineered systems. Customers repeatedly come to us for practical solutions to demanding technical problems. We are able to rapidly design and deliver solutions. Such is the case with the Idaho Integrated Breaching Shotgun, which facilitates rapid entry with increased safety to our nation's law enforcement officers. Our staff developed a working prototype in just two months.

This issue's cover story features UAV – unmanned aerial vehicle technology – an exciting growth area for the laboratory. Homeland security applications using inexpensive UAVs are limited only by the imagination. Border control, energy infrastructure surveillance and emergency communications are three near-term applications we are pursuing. In the next year, we hope to demonstrate the use of UAVs to enhance surveillance of the INEEL site.

All of these technologies are being developed by a premier engineering laboratory and are tested and demonstrated on our 890-square-mile site – a versatile place for testing and demonstrating advanced technologies.

When Seconds Count

Idaho Integrated Breaching Shotgun

Contributed by Stacey Francis

Sometimes, seconds can mean the difference between life and death, between mission success and failure. When facing unknown dangers lurking beyond a locked door, police officers or military personnel may need to get in fast without relinquishing control of the situation or their weapons.

Recently, a federal law enforcement agency approached the laboratory to help solve a problem facing its agents. The agency wanted INEEL engineers to design a better firearm for use in executing forced entries through doors. A traditional entry method requires a shotgun to breach doors. In the standard process, the shooter fires at the door to destroy the hinges or the lock and then either has to switch from the shotgun to an assault rifle or remove himself from the line of fire to allow others to proceed through the door. Either way, the loss of precious seconds could result in undesirable consequences.

A request for a multiple-shot shotgun bolted on to an assault rifle came through the Department of Energy Office of Intelligence's Applied Technology Program – a program within DOE that matches technology needs throughout the federal arena to researchers within the national laboratory system. This client hoped to find a design that would allow improved entry times in life-threatening situations and lower risks to its agents.

Steve Frickey, an advisory engineer in National Security's Nonproliferation organization, had encountered the same problem years earlier when he shot a very cumbersome and awkward weapon system used by the military. Frickey had contemplated how to improve the design of an assault rifle and shotgun used together.

"It seemed obvious to me that there was a better way to do it," he said. "When I saw the request for such a weapon, it seemed an opportune marriage of an idea with a need."

Frickey prepared and submitted the original proposal that was accepted.

That's when Mike Occhionero, the INEEL contact for the ATP got involved. Once the customer was convinced the INEEL had the experts, ideas and commitment required to solve the problem, Occhionero went to work establishing the requirements and putting together a project team.

David Crandall and Rich Watson from the National Security's Special Programs group took the requirements and began work on the Idaho Integrated Breaching Shotgun. Frickey continued in an advisory role.

David Crandall and Rich Watson assemble the Idaho Integrated Breaching Shotgun prior to a demonstration of its capabilities.

"Because the customer had more experience than we did in the actual application, we involved them in every step of the design process," said Occhionero.

Crandall, Watson and Frickey accepted the challenge of designing the special compact weapon and integrating it with the operator's primary weapon. Crandall said the importance of the combined weapon system was critical as repositioning or switching guns wastes too much time in breaching situations.

"Seconds or even parts of seconds can mean all the difference," said Crandall.

With no firearm existing to do the job, the team's solution was to redesign the traditional 12-gauge pump shotgun and make it work differently.

Standard shotguns cycle cartridges by moving the bolt to the rear. In the new design, the bolt is held stationary and the receiver and barrel move forward, allowing the receiver to be shortened and the barrel to be lengthened. Keeping the barrel longer provides more time for the powder to burn and more energy to be applied, making the shotgun more effective. The Idaho Integrated Breaching Shotgun is three inches shorter overall while incorporating an effective barrel twice as long as anything else currently available.

Rich Watson displays the Idaho Integrated Breaching Shotgun design. In the new design, the bolt is held stationary and the receiver and barrel move forward.

The Idaho Integrated Breaching Shotgun also incorporates a replaceable box magazine making it easier to rapidly reload and select alternate munitions, such as less-than-lethal rounds.

Watson says creating an entirely new firearm in about four months for very little money was extraordinary. Occhionero echoes that feeling.

"Typically, a gun design program is a multiyear, multimillion dollar proposition," Occhionero said. By using many already existing components in an innovative way, the team was able to design the prototype in a little over two months. Achieving a functional prototype in such a short time was due, in part, to the expertise of machinists Jimmy Johnson and Travis Brown.

The team says the INEEL's security force also played a major part in the success of the project.

"You can't just bring a federal agency's assault rifle to work," Occhionero said. "We had to address a lot of paper work and policy issues before we could bring the gun onto the INEEL for non-security purposes. Our security force, along with DOE, worked those issues for us and made it possible."

Occhionero reports that the client was impressed with the gun during the recent demonstration. If the team obtains additional funding, it will pursue ways to decrease the weight and improve other ergonomic factors.

Because of the ingenuity in the design, the developers are applying for five patents and an R&D 100 award, and they are considering further enhancements to the system.

Discussions are already underway with a gun manufacturer interested in producing and marketing the integrated breaching shotgun.

According to Watson, being involved in the project was even more exciting due to one fact, "It was cool to work with guns and get paid for it!"

Mike Occhionero
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A federal law enforcement officer fires the new breaching shotgun. Because the customer had more experience in the actual application, they were involved in every step of the design process.

Guest Speaker Tells of Active Spying

Contributed by Jack Way
Senior Counterintelligence Officer

INEEL Counterintelligence regularly invites guest speakers to talk with employees, and occasionally, the public. Last year, we sponsored four presentations – on laptop security, terrorism, cyber security and spying.

A Russian Military Intelligence (GRU)[1] defector who went by the name of "Stan" gave the final presentation on spying. I would like to share some of his comments made during this lecture.

According to Stan, the United States is still the GRU's number one target. The GRU continues aggressive collection efforts against the U.S. in preparation for war, which they believe is inevitable. The GRU has officers located around the world as well as those assigned undercover throughout Russia to spy on its people. If a GRU officer approaches a Westerner, whether in or out of Russia, the officer will already know extensive details about the individual.

Stan stated that Russian leaders have built an underground bunker beneath Moscow, equivalent in size to the beltway around Washington, D.C., where the leaders could reside during hostilities. He said there is a secret military bunker in Siberia capable of withstanding a nuclear attack, and there are many nuclear-equipped missiles on mobile platforms throughout Russia, making them hard to detect.

Stan claimed that Russian special forces are living and traveling in the United States as citizens and tourists and are prepared to attack key civilian and military leaders and key infrastructure targets if ordered to do so. At more than 120 sites worldwide, Russians have buried weapons and equipment to support this mission. He stated that although nuclear devices have been stolen from former Soviet Union countries, they cannot be detonated, but could be used as "dirty bombs."

Stan painted a bleak picture of Russian economics, stating that there is no true democracy in Russia but rather a "managed democracy." The sound Russian economic reports are falsified and the true status is very critical. All "free" press/TV stations have been closed down and there is massive corruption throughout Russia.

He reported that organized crime controls 75 percent of the businesses in Russia. Russian intelligence services and communist party members are actively involved with, and sometimes control, organized crime elements. Many retired KGB officials work for organized crime and the Russian Mafia is trying to gain ground in the United States.

As a final warning to the INEEL audience, Stan reiterated that GRU scientists are working and traveling in the scientific community. GRU officers are always on the lookout to recruit Americans, and Russian spies pose as scientists, students, diplomats, and businessmen. Everyone collects information – actual students, scholars, scientists and businessmen – not just intelligence officers.

[1] *Glavnoye Razvedyvatelnoye Upravleniye (Soviet Military Int)*

According to a GRU defector, Russian leaders have built an underground bunker beneath Moscow, equivalent in size to the beltway around Washington, D.C. where the leaders could reside during hostilities.

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