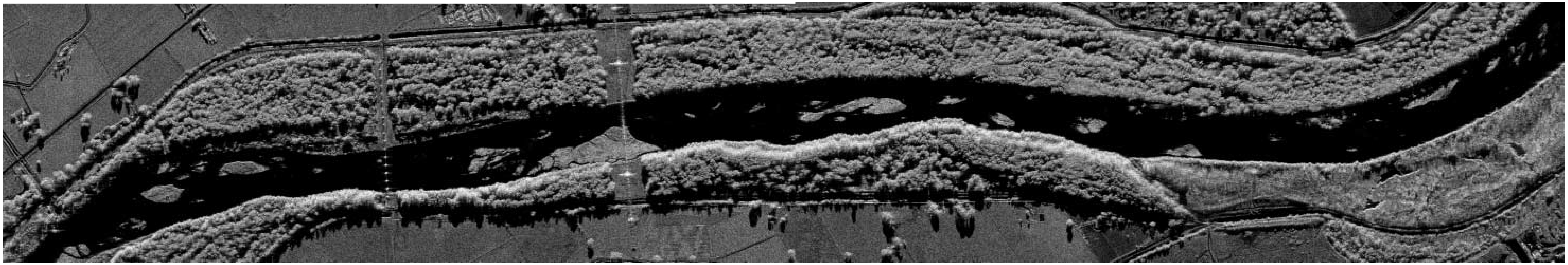


PICTURED ABOVE is a synthetic aperture radar (SAR) image at a 0.5-meter resolution depicting three miles of the Rio Grande south of Belen, N.M. Below is a photograph taken by Randy Montoya that shows Katherine Simonson and Wallace Bow (both 15352) on a Russian T72 tank. It was one of several military vehicles used in a recent SAR test at McIntosh, N.M.

Sandia uses sophisticated synthetic aperture radar to collect information about military vehicles

Area near McIntosh, N.M., looks like war zone, but it's only a test

By Chris Burroughs

Anyone visiting McIntosh, N.M., 30 miles east of Albuquerque, in recent weeks might think they had entered World War III.

Some 17 different military vehicles, including tanks, surface-to-air missile launchers, armored personnel carriers, and a transporter erector launcher — many captured from US adversaries during military operations like the Gulf War — were scattered over a 160-acre area near the small New Mexico town between May 21 and June 22.

No, it wasn't World War III. Instead, it was part of a test of a sophisticated Sandia-developed synthetic aperture radar (SAR), a flexible, calibrated sensor capable of providing photographic-like images through clouds, in rain or fog, and in day or night conditions, all in real time. SAR uses the reflective properties of radio waves to form images of features and objects in the air or on the ground or water (See "How SAR works," below left).

Project lead Wallace Bow of Signal and Image Processing Systems Dept. 15352 says the intent of the three-week mission was to use SAR to collect significant amounts of information about each of the military vehicles that could be put into a computer database and retrieved later to identify similar vehicles in other settings. During this mission, the team collected nearly a terabyte (1 trillion bytes) of SAR data.

The SAR was mounted on a DOE-owned DeHavilland DHC-6 Twin Otter aircraft that made hundreds of early-morning swoops over the military vehicles, taking radar images of each from multiple angles. The plane carried a complete data collection system including radar, Global Positioning System (GPS)-aided inertial motion measurement system, a fully gimbaled antenna, a real-time image formation processor, and a high-capacity data storage system.

Powerful algorithms

The SAR image data are fed into powerful computer algorithms for Automatic Target Recognition (ATR) modeling. Each image of a vehicle has its own unique "signature" that was captured for use in the ATR algorithms.

"The images we collect will contribute to statistical models of these targets, which are stored in an ATR database," Wallace says. "Then, in a real-life situation — like when the Air Force needs to identify particular time-critical targets — the ATR can help determine which of those targets might be present in a SAR image."

ATR processing is useful to image analysts because SAR produces images at rates far higher than humans can visually review them. ATR systems can be used to cue human operators to specific regions of interest, reducing the time required for the analysts to review each image. More complete ATR systems that include an identification algorithm can fully identify and locate targets without human intervention and with low false alarm rates.

The ATR processes SAR imagery in three stages and adds annotations that can aid image analysts in interpreting the image's contents. In the first stage of the algorithm, the computer program places a green box around the part of the SAR image that appears to be the right shape and size of a possible target. In the second stage, a yellow box is drawn around a location that looks even more closely like a potential target. In the third, a red box is drawn around a declared target location.

If the ATR is "trained" to find a particular vehicle, the computer program will readily identify the target. If not, it will reject the image as "unknown."

"Fortunately, Sandia has a unique capability in the Twin Otter data collection platform that allows us to fly circles around the targets and form enough SAR images in real-time to accomplish our ATR training objectives," Wallace says. "We can collect enough data to completely train and test our algorithms in just a matter of days."

Working closely with Wallace and his crew are members of Center 2300 who develop high-performance SAR systems. The development of the X-Band (7-10 GHz) polarimetric SAR, led by Dale Dubbert (2345), was part of the Advanced Radar Systems (ARS) project sponsored by Randy Bell of DOE's Office of Nonproliferation Research and Engineering (NN-20). Center 2300 personnel, who routinely set up different imaging radars on various airborne platforms, also make sure they are operational and are responsible for collecting the radar images. As part of this effort, the data were delivered to Dept. 15352 for input into the ATR.

Takes a trained eye

Dale says it takes a trained eye to tell that a small object on a radar image is a tank and differentiate it from a car or other vehicle. But when people are trained in SAR image analysis, they can easily determine what they are seeing.

"There are a whole lot of nuances involved," Dale says. "You have to be aware of things like shadows, which may make one thing look like something else."

Wallace says that during the three-week test period his department had at least two people a day at the McIntosh site. They would go out early in the morning to plan where the vehicles were to be set up and in general did site survey and planning. They also planted survey flags, which will help later when identifying specific military vehicles.

"We've run into some unexpected occurrences during this data collection that we have discovered we have to check for every day — things like cows roaming the pasture and eating survey flags or knocking down tables containing our reference reflectors," Wallace says.

Data collected in the project will eventually become part of an ATR system that will be used by Department of Defense clients.

How SAR works

The following is an explanation by Armin Doerry of Synthetic Aperture Radar II Dept. 2345 about how synthetic aperture radar (SAR) works.

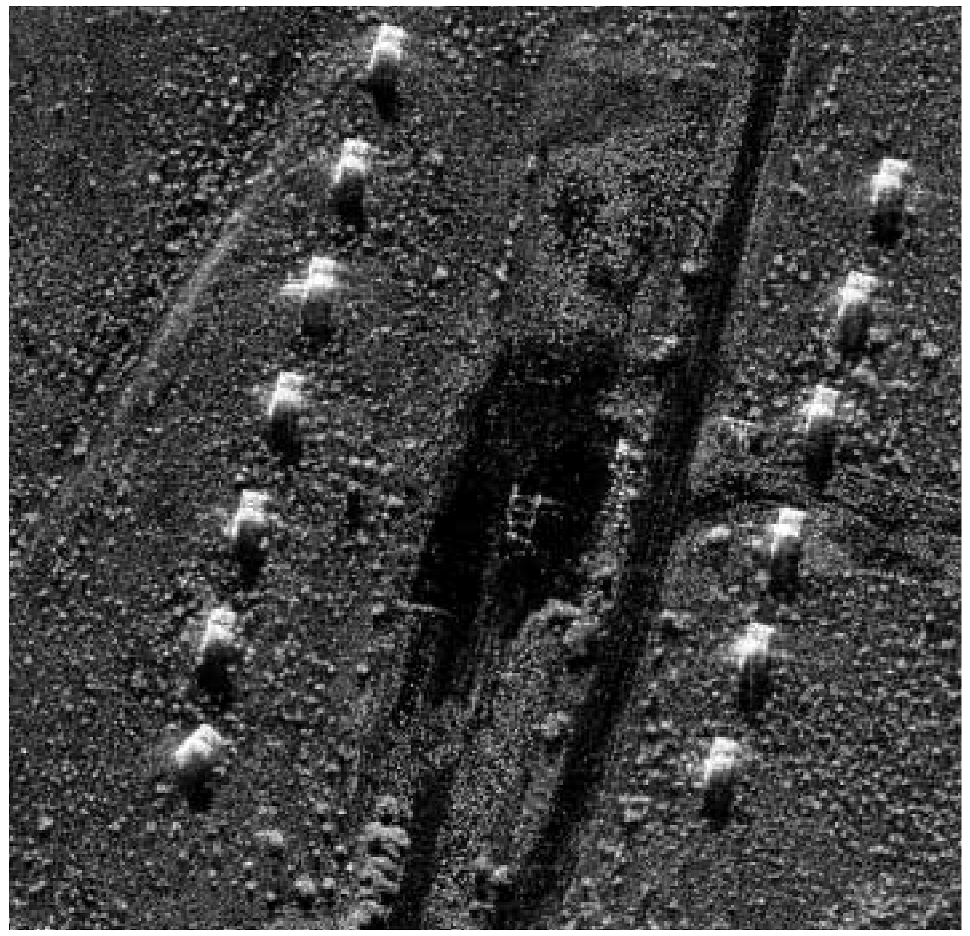
In order to explain how SAR works, think first about a simple radar that sends out a signal, which bounces off a target and returns to the radar as an echo. The timing of the return echo is determined by the speed of the radar wave — typically the speed of light — and how far it has to travel. As the signal travels its path, it bounces off different targets with each strike producing an individual echo. These echoes all return to the radar where they are received as a single combined echo signal.

The exact nature of the combined echo signal depends on the relationship between the individual target ranges. If the radar is moved to a new position to gain a different perspective of the target set, the relationship of the ranges changes, as does the nature of the new combined echo signal. By tracking how the various components of the combined signal change as the radar moves, the various target returns can be separated.

An airborne SAR takes a number of radar soundings from along some precisely measured flight path and then separates the various target locations by sophisticated signal processing. This allows the formation of extremely detailed fine-resolution maps of the radar-reflectivity of a target scene — SAR images.

Combining many radar pulses over a spread of viewing angles into a single data set is 'synthesizing' an 'aperture' (a term borrowed from optics), hence the name synthetic aperture radar. The spread of viewing angles — i.e. the synthetic aperture length — as well as the bandwidth of the signals used determine the resolution with which the SAR images can be formed. The process is very similar to Computer-Aided Tomography (CAT) scanning used effectively in medical imaging.

WALKING THROUGH the test site near McIntosh, N.M., filled with 17 different military vehicles are, from left, Jose Salazar, Gene Smit, Katherine Simonson, and Wallace Bow (all 15352). The vehicles were part of a three-week mission to collect significant amounts of information about them using Sandia-developed synthetic aperture radar.
(Photo by Randy Montoya)



THIS SAR IMAGE at a 15-centimeter resolution shows tanks parked at the south end of the Sandia sled track. It takes a person trained in SAR image analysis to determine the type of vehicle being visualized.

BRIAN BRAY (15352) is next to a Sandia-built Automatic Target Recognition (ATR) system that was installed on a US Air Force aircraft. The picture was taken during a June 8 test separate from the McIntosh mission.