Miller-McCune TURNING RESEARCH INTO SOLUTIONS

Finding Water from Outer Space

By: Vince Beiser Print

The Land Cruiser rattles and bumps down a stripe of rutted dirt carving through the brush in this remote corner of southern Angola. Half a mile to the west, the tranquil blue Atlantic glimmers in the African sun. To the east, miles of spiky desert grass fade away to a range of sere mountains. The last village lies miles behind us, the next miles ahead.

In the front seat, Alain Gachet, a plump, boyish 58-year-old, his thick crest of silver hair crammed under a leather Indiana Jones hat, is focused intently on the laptop balanced on his knees. The computer is plugged into a tiny GPS unit set on the dashboard. On the screen, a thin yellow line tracking our progress creeps forward over a map stippled with thousands of differently colored squares.

"Stop here!" Gachet cries suddenly.

The driver brakes in the middle of the track. By the time three South African drillers and I extricate ourselves from the cramped vehicle, Gachet has bounded out, scrambled over a hillock and found a low, clear patch of sandy yellow soil.

"Right here, Freddy," Gachet requests in French-accented English.

Freddy Chambers, the beefy lead driller whose thick salt-and-pepper hair and mustache lend him a passing resemblance to Saddam Hussein, drives a shovel into the earth. Gachet practically vibrates with excitement as he watches. About 2 feet down, muddy gray water starts bubbling into the hole. Both men's faces split into grins.

Gachet fills an empty juice bottle with the cloudy liquid, strains it through a portable filter and drinks. "Fresh water," he says and bursts out laughing.

It's an extraordinary find, not only because the area is so dry, but because underground water this close to the sea would normally be too salty to drink. Gachet knew there would be fresh water in this spot, though; messages from outer space told him so.

Finding more fresh water is one of the paramount challenges of the 21st century. Nearly one-third of the human race lacks reliable access to clean water, according to the [redacted]. Some 3 million people — most of them children — die every year from diseases spread by contaminated water. A 2007 report by the U.N. Environment Program predicts that by 2025, if population growth and environmental degradation continue apace, 1.8 billion people will live in countries with "absolute water scarcity."

A former oil industry geologist, Gachet has developed a path-breaking, high-tech system that could help slake

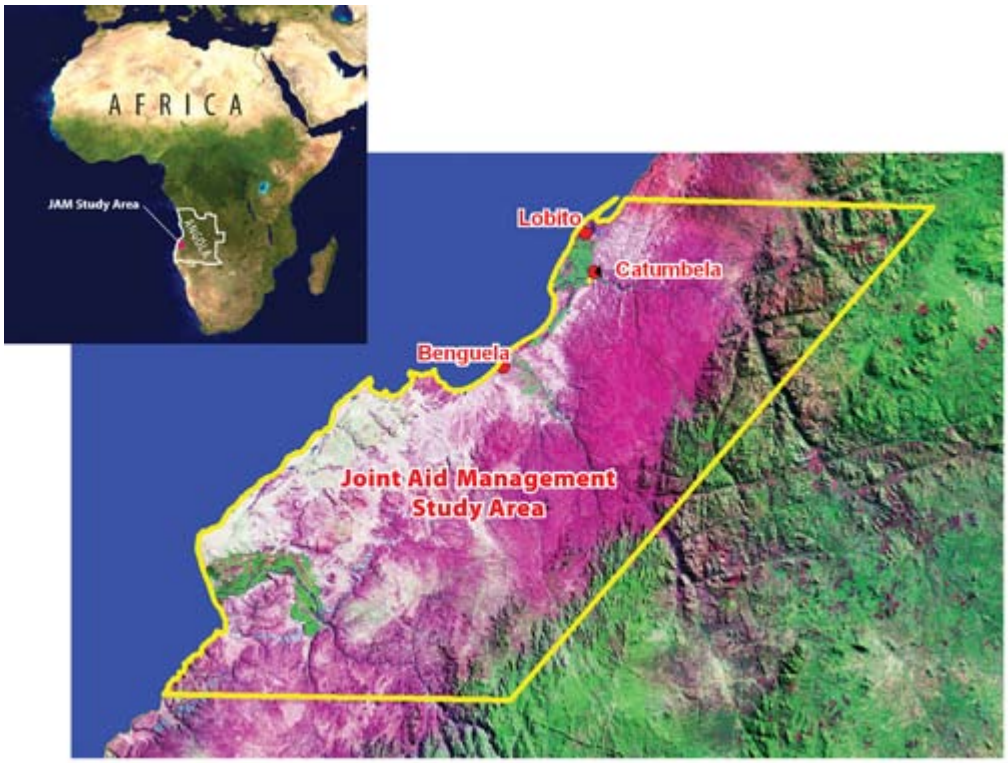
that growing thirst. The key: using satellites high above the Earth's surface to see what's underneath it.

By combining terabytes of space-based photographic imagery, ground-penetrating radar and topographic data — much of which has only recently become available — Gachet creates multispectral maps that are proving excellent guides for finding undiscovered underground aquatic resources. At the height of the Darfur crisis, the United Nations called on Gachet to help find sustainable locations for camps in Chad that now house thousands of refugees. It was the first time such technology had been used in a humanitarian emergency. "Gachet's work was an extremely important contribution at a time when it was not sure that [the U.N.] would be able to provide water for the long term for all refugees," says Marc-Andre Bunzli, a former U.N. official who worked with Gachet in Chad. Since then, Gachet has located water in Darfur itself, as well as in parts of Afghanistan, Iraq and Eritrea.

I joined Gachet last summer for the kickoff of a new project. Joint Aid Management, a South Africa-based humanitarian group, recently began a campaign to provide food and water to some 450 schools scattered over hundreds of miles in war-blasted Angola. Because it costs an average of $10,000 to bore a hole for a well, the group has a major incentive to increase its hit rate. Joint Aid Management brought in Gachet to help them figure out where to dig.

"It's the first time I'm working not in a war zone but in a reconstruction area," Gachet told me when I first met him in JAM's compound, a fenced-off patch of desert full of trucks, housing trailers and a small processed food factory on the outskirts of Benguela, a coastal city in southern Angola. "Emergency situations are very frustrating. You maintain people in camps, but you don't deal with sustainable development. It's crazy, because you create a generation of beggars. Here, I hope the wells can bring prosperity and stability."

This beleaguered southern African nation can certainly use both. Colonized by Portugal for centuries, Angola won independence in 1975 after a lengthy guerrilla struggle — only to plunge almost immediately into an even more devastating civil war. The two main factions became Cold War cat's-paws, with the Soviet Union and Cuba arming the governing Movimento Popular de Libertacao de Angola, and the U.S. and South Africa backing the rebel Uniao Nacional para a Independencia Total de Angola. The fighting ground on for 27 years, until the MPLA finally beat UNITA down. The war left as many as 1.5 million Angolans dead, factories and cities in ruins, and roads and farms infested with landmines.



Today, seven years after the shooting stopped, Angola is still pretty much a basket case. The United Nations ranks it as one of the world's poorest countries despite its enormous natural resources. Twice the size of Texas, Angola is rich in diamonds, gold and other minerals, not to mention enormous oil reserves that are only beginning to be seriously tapped. New five-star hotels are surging up from the potholed streets of the capital, Luanda, and a tiny elite with connections to President Jose Eduardo dos Santos is reportedly pocketing fortunes in petro-dollars. But there's not much sign of that new wealth elsewhere. An estimated 70 percent of the nation's 13 million inhabitants live on less than one U.S. dollar a day; 35 percent are malnourished. A chronic lack of basic sanitation and health care help give Angola the world's second-highest infant-mortality rate. Those who survive can expect to die before reaching the age of 42.

Lack of clean water is one of the key factors driving those appalling statistics. One day, I visited a children's hospital in Cubal, a small town in the grasslands southeast of Benguela. Cubal consists of a few streets of government offices and shops housed in low cement buildings, surrounded by acres of mud-brick huts roofed with thatch or corrugated tin held down with rocks.

In the spartan hospital, dozens of scrawny, undersized children sprawl listlessly on thin mattresses or lie in the arms of their stoic mothers. One or two cry insistently, but quietly — they don't have the strength to scream. Many have the distended bellies and open sores that indicate extreme protein deficiency. Nearly all have severe diarrhea, an ailment that's typically caused by unclean water and can be fatal if left untreated. Every now and then, outbreaks of water-borne cholera bring in even sicker kids.

How big a problem is water? "Grandissimo," says Sister Milagros Moreno, the redoubtable Spanish nun who has worked in this church-run hospital for 18 years. "Most people get their water from the river. It's very contaminated. Everyone washes their clothes and bathes in it. But people don't have enough wood or gas to boil the water. Wells would be a huge help."

Gachet has been investigating what lies beneath African soil almost his entire life. He was born in northern Madagascar in 1951, the son of French colonial civil servants. His father, a botanist, started taking him on

treks into the rainforest when he was 4 years old. That's when Gachet fell in love with rocks. Prehistoric fossils were everywhere. He was fascinated by the story of how the continents had split apart eons ago, leaving the history of their union inscribed in layers of subterranean stone.

As an adult, naturally, he became a geologist. He worked for ELF, the French oil giant, for two decades, helping to find new oil and gas fields from Gabon to Holland's portion of the North Sea. "I've always been involved in exploration," he says. "I tell people where the wealth is, how deep down and how they can reach it by drilling."

But he grew disillusioned working in The Republic of Congo during the civil war of the 1990s. "I was the one who had to co-sign our checks to the government. It was clear the money was going to buy weapons," Gachet says. "I was losing the pride of working for this company."

So he set up his own, which he eventually dubbed Radar Technologies International. In 1996, Gachet was contacted by a mining outfit that wanted to locate the source of the gold their Pygmy workers in The Republic of Congo kept finding in rivers. There were few maps of the area, and aerial photographs were no help; the rainforest canopy was too dense.

Gachet turned to two new pieces of technology. Using an early GPS unit, he followed the Pygmies into the jungle, marking the spot in each river where they pulled out nuggets. Then he bought newly available radar images of the area taken by the American space shuttle. The radar could penetrate clouds and jungle to give Gachet a rough sense of the shape and texture of the land beneath — big clues to its underlying geology. By overlaying those images onto his GPS data points, he was able to locate the gold's source. "I had the illumination that I was in front of a completely new way to explore the planet," he says.

That "new way" is known as remote sensing — the use of imagery collected from space to find things on the ground. Gachet has integrated a suite of such technologies into his exploratory work. C-band radar used by satellites maintained by Canada and the European Space Agency penetrates the ground to a depth of about 50 centimeters. Japan's JERS-1 satellite provides L-band radar, which goes down as far as 18 meters. NASA's Landsat satellites record images of the Earth using eight different wavelengths, from infrared to visible light. The most recent addition to this arsenal of space-based imagery became available in 2004, when NASA released topographical data gathered by the space shuttle. That has enabled researchers for the first time to create 3-D views of any area on the planet. "It's a fantastic gift from the United States to the world," Gachet says.

Using these technologies, Gachet continues to find oil, diamonds and other subterranean treasures for big corporations. In 2002, while studying radar images of the Libyan desert for Shell, he noticed evidence of huge amounts of moisture underground. After some research, he realized he was looking at leaks from Libya's "Man Made River." One of President Muammar Qaddafi's proudest achievements, this colossal underground pipeline carries water from an aquifer under the Sahara to the desert nation's coastal cities. "Billions of cubic meters of water were being lost into the sand," Gachet recalls. He passed on his findings to the Libyan government and a few months later, was surprised to find himself giving a personal presentation to Qaddafi. Gachet was hoping to win a contract to monitor the pipeline. He never heard back about that — but he did hear from friends that a furious Qaddafi had executed the engineers in charge of the project. (The Libyan embassy would not comment when I asked about this incident.)

That was the beginning of a new chapter for Gachet. "I thought, 'You are finding leaks,'" he says. "'That means you can find groundwater that no one else can see.'" He began building a system, dubbed WATEX, to find water by remote sensing.

The process involves mapping the geology not just of the targeted area but of the entire watershed that feeds into it. Topographical data is an essential ingredient, allowing Gachet to see slopes that water would run down

and flat areas where it might pool. Ground-penetrating radar shows fractures and natural dikes that affect the course of water's flow. Radar has a critical shortcoming, though, when it comes to reading the ground's surface: It makes a rough, pebble-strewn surface look the same as one containing significant moisture. One of Gachet's key breakthroughs was figuring out a process for telling the difference between the two.

Gachet's WATEX was well developed by 2004 when he got a call from a friend working with the U.N. High Commissioner for Refugees. "He said," Gachet recalls, "'We have 250,000 refugees along the border between Sudan and Chad; they are dying like flies. Can you help? Quickly?'" Gachet agreed and spent the next four months working up a map of some 80,000 square kilometers of the area.

Gachet does most of the work on computers in his home office in a 15th-century chateau in southern France. But to be sure of his results, he has to get his feet in the mud. Later that year, a U.N. plane dropped him in the eastern Chadian city of Abeche. From there, he and a driver set out by Land Rover to the desert refugee camps.

"It was the most terrible thing I ever faced in my life," Gachet recalls. "Children with bullet wounds. The dead being collected in trucks."

Gachet spent days inspecting the areas WATEX indicated contained moisture. He marked the ones that panned out with a pile of rocks and his own handprint in white paint. Along the way, he and his driver strayed into a minefield, got lost in a sandstorm and ran so low on food they had nothing to eat but onions and locusts. "He's a very courageous guy," says Firoz Verjee, a water researcher at George Washington University's Institute for Crisis, Disaster and Risk Management who has worked with Gachet. "He'll outdo you on risk every time."

Photo by Walter Fernandes

A girl draws water in Dombe Grande Village.

The mission was a success. The UNHCR used Gachet's data to help select sites for four new refugee camps and rule out seven others. Five years later, "we are still using his excellent maps," says Christian Guillot, UNCHR's head of water issues for eastern Chad.

On the strength of that job, Gachet was contracted by the U.S. Agency for International Development to map all of Darfur —another 135,000 square kilometers. According to Abdalla Abdelsalam Ahmed, who holds the U.N. Educational, Scientific and Cultural Organization chair in water resources at Khartoum's Omdurman Islamic University, the WATEX data increased the drilling success rate from 33 percent to more than 90 percent, halving associated costs and significantly speeding up work. The amount of water found near the biggest refugee camps is enough for several million people. At least 300 wells have been dug based on Gachet's water-target map.

In Angola, Gachet had to start practically from scratch. "Much of the geological information was destroyed during the fighting, and there's no rainfall data, because who cared about collecting that during the war?" he says.

So from his desk in Provence, he used remote sensing to build his own geologic map of 5,000 square kilometers of southwestern Angola. It shows the various rock layers, soil types and fissures, and how all those

factors conspire to direct the underground flow of water from inland rainfall and rivers toward the coast. Once his multidimensional map was ready, he hit the ground to see how accurate it was.

The coastal plain where most of Joint Aid Management's schools are located is semi-arid, an area reminiscent of Southern California, with rolling, dun-colored flatlands and hills stubbled with wiry grasses, bushes and cacti. There's certainly some water here; a number of rivers and streams cut through on their way to the sea. In each one we pass in the Land Cruiser, children swim, women wash clothes and men bathe, and, often, clean their prized motorbikes. Goats, pigs, cows and dogs roam on the banks, relieving themselves where they will. It's an exuberant, colorful scene — but it makes for tremendously unsanitary water.

Under such circumstances, wells are the best bet for drinking water — preferably wells deep enough to be free of contamination by animal and human waste and other toxins. The tricky part is figuring out where to dig them. "In most places, we literally drive around for days looking for promising spots to drill," says Chambers, the South African driller.

Gachet is spending a full week exploring the area to confirm and fine-tune his findings. He scrambles up and down hillsides like a merry mountain gnome, breaking off bits of stone with his ever-present hammer, determining the area's geologic makeup. He notes verdant strips of trees and grasses running through the scrubby flatlands — evidence that the underground water-carrying fracture he expected to find is indeed there. Whenever a village appears in an area where his map indicates there's an underground aquifer, he investigates. More often than not, the locals have already dug some kind of well, proving the existence of the aquifer.

In one little copse of scraggly trees, for instance, we find a circle of stones, cemented together and with two railroad tracks set across the top. A barefoot man in shorts and a T-shirt is hauling up bucketloads of water by hand to fill a collection of plastic jerry cans. Later he'll lug them back to his village of mud-and-thatch huts about a mile away. In another unpromising patch of scrubland, we encounter a handful of women, several with infants lashed to their backs with colorful cloths, washing clothes in plastic tubs. The water they're using comes from a well that is nothing more than a hole at the bottom of a hand-dug crater. Gachet scurries down to sample the water, much to the women's surprise and amusement. Each of these grains of information — well location, water quality, type of stone — is added to the WATEX database, constantly refining Gachet's picture of the area.

Gachet isn't the only researcher using satellites as modern dowsing rods. Farouk El-Baz, a researcher at Boston University, made headlines in 2007 when he announced that, using remote sensing techniques similar to Gachet's, he had discovered what appeared to be a vast lake of water hidden beneath the blood-soaked sands of Darfur.

The Egyptian-born El-Baz has a serious track record. He spent the late 1960s training NASA astronauts on lunar and earth geology. Since then, he's turned his attention to finding water in deserts, studying wastelands from the Arabian Peninsula to India. Several years ago, he discovered a massive underground aquifer in Egypt that today irrigates 150,000 acres of farmland.

El-Baz's purported lake could have enormous ramifications because Darfur's chronic and worsening water shortage is one of the key factors setting the locals at each other's throats. Soon after announcing his discovery, El-Baz met with top Sudanese and Egyptian government officials as well as U.N. Secretary General Ban Ki Moon. All concerned promised to back a major effort, grandly titled "1,000 Wells for Darfur," to develop this underground aquatic resource.

But two years later, not a single hole has been drilled. El-Baz says the ongoing fighting has kept him from taking a technical team to do the on-site geophysical research required to confirm the water really is there,

and if so, precisely where. (Gachet, incidentally, thinks El-Baz is mistaken, and that the lake has long since dried up.) In the meantime, much of the initial enthusiasm around the project seems to have evaporated. The Egyptian government, which had promised to drill 40 wells in the lake area, is now looking elsewhere. The United Nations was willing to help, El-Baz says, but no one ponied up funds. The "1,000 Wells for Darfur" Web site has been taken down. The only firm commitment is from the Sudanese government, which has promised to dig a grand total of five wells. At best, El-Baz says, it will be a year before any drilling begins.

Photo by Walter Fernandes

A child carries water from a well near Baia Farta.

That story points out the limitations of the work El-Baz and Gachet do. They may be able to find water — but the water might not be where it's needed. El-Baz's purported lake is in Sudan's northern desert, nearly 200 miles from population centers. Even if there is water there, the wells to tap it will be fantastically expensive — about $500,000 each, El-Baz estimates. "There's no road anywhere near the place," he explains. "They will need to bring in everything — quarters, water, equipment, food."

Politics is at least as big an obstacle as logistics and cost. One of the lake project's most enthusiastic backers, El-Baz says, is Sudanese President Omar al-Bashir — whom the International Criminal Court recently indicted on charges of committing atrocities against the people of Darfur. The indictment raises a question: What would Bashir actually do with the water?

"New water resources provide as many perils as hopes depending on the politics of how the water is controlled," Darfur expert Alex de Waal wrote in a recent paper for the Social Science Research Council about El-Baz's underground lake. Those resources could be used for the benefit of all, "[but] given the opportunity, Khartoum is likely to utilize [them] to reward its local allies with ownership of the most productive new farms." De Waal's conclusion: "The aquifer is no solution to the region's crisis, and if mishandled could even worsen the conflict."

Even in the absence of such ugly politics, the overall lack of development in much of sub-Saharan Africa means that just finding and drilling a well isn't enough. "We have a systematic problem of wells not being maintained," says Anthony Jones, JAM's program director for southern Africa. "We come in, drill a well, install a hand pump. But a year or two later, the pump breaks, and the local people don't know what to do. So they go back to hand-dug wells and other less-safe water resources."

The remote sensing work isn't cheap, either. Gachet volunteered his time on the ground in Angola but did charge JAM $50,000 for creating the water-target map.

In short, Gachet's WATEX system is no silver bullet for the developing world's water woes. But it can certainly help. "The technology far surpasses our expectations," says Jim Lutzweiler, JAM's head of strategic development. "It's like moving from a Toyota to a Mercedes, in terms of the amount of detail it provides. It's going to increase our hit rate tremendously."

And WATEX has applications beyond simply targeting wells or even finding new sources of water in emergency situations. It can support long-term development. The system can, for instance, identify the best places to build dams across wadis, capturing the rains that briefly flood arid places — eastern Chad, for example — every winter. It can also identify agriculture-friendly soil types and economically valuable

mineral deposits. "It's expensive, but it's a great development tool," Jones says. "I can see it being very useful to us in terms of figuring out where schools and towns should be."

Gachet is thinking bigger. He's planning trips to the U.S. to try to drum up interest from major foundations and other potential backers to apply WATEX on a massive scale. "We could create a consistent picture of all of Africa and make the results available to anybody," he says. "WATEX should allow us to avoid future wars linked to water."

That goal is perhaps a tad ambitious. Remote sensing is, after all, just a tool for finding water, and tools can always be misused. But put to work properly, this one can make a critical difference.

In Cubal, after showing me the hospital, Sister Moreno gives me a tour of the rest of the compound. It includes a sizeable church and an elementary school full of children in unmatched but uniformly spotless white shirts. In the school's courtyard, a group of boys and girls cluster around one of the key resources that keeps them healthy when so many other local children aren't. One by one, they wash their hands under the trickle dribbling out of the metal pipe of a hand-pumped well, then cup them for a drink of clean, fresh water.