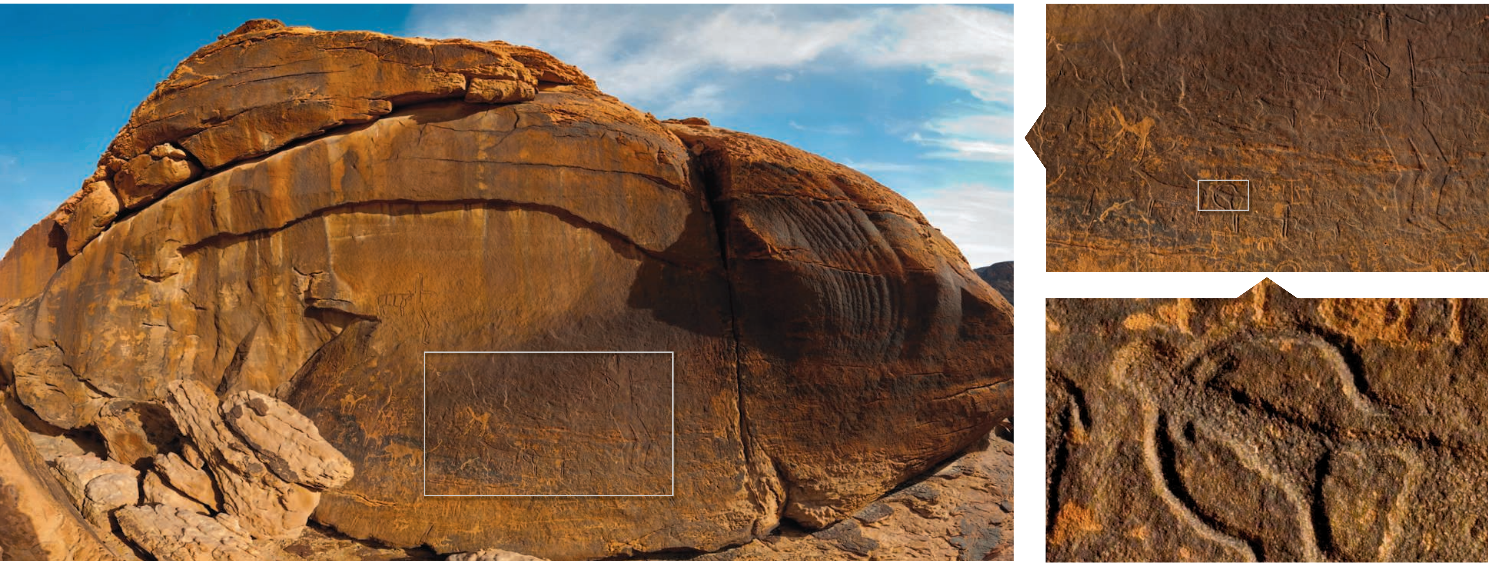

Rock art. A GigaPan of a remote outcrop in Saudi Arabia helps see and date drawings chipped through the "desert patina" on the rock face.

Panning for Science

A new technology for creating and viewing stunningly high-resolution panoramic images is becoming a powerful research tool

WHEN NASA'S TWIN MARS ROVERS BEGAN sending detailed pictures to Earth in January 2004, Randy Sargent, a computer scientist working on visualizations of those images, was enthralled by the sense of actually exploring martian terrain. Onboard each rover, a camera known as the Pancam swiveled and tilted on command from NASA scientists. Sargent and his colleagues combined each exposure into a stunning digital panorama of the Red Planet's landscape. Scientists at the Jet Propulsion Laboratory in Pasadena, California, could interact with the images on their computer screens, zoom in on fine details, hypothesize about what they were seeing, and pick the rovers' next destinations. "The pan had so much resolution, it felt like peering through a little hole in the wall into another world," recalls Sargent's manager, robotics group leader Illah Nourbakhsh at NASA Ames Research Center in Moffett Field, California, who was then on sabbatical from Carnegie Mellon University (CMU) in Pittsburgh, Pennsylvania. "What stunned us was this feeling of presence, which a simple picture that is not interactive doesn't give you."

That experience led directly to a technology that has become a powerful tool for teaching and public engagement with science and the natural world. Scientists are also using it for projects as diverse as analyzing Middle Eastern petroglyphs, monitoring an urban forest, archiving a museum insect collection, studying a collapsed honey bee colony, keeping tabs on glaciers, examining erosion in a jaguar reserve, and viewing Galápagos fish clustered into a bait ball.

Soon after the martian panorama renderings, Nourbakhsh challenged his team to think creatively about "blue sky" projects they could tackle. Aware of the intense reverence astronauts felt as they gazed at Earth from space, Sargent proposed bringing that kind of experience down to Earth by building affordable equipment anybody could use to create explorable images. Nourbakhsh immediately recognized the idea's potential for changing the relationship between viewer and image. "An explorable image is a disruptive shift away from the static image you just glance at, because now you have the power of exploration," he says. "That sets people up with a different mindset because *they* decide where to zoom, where to go, what structures and details to see. And it's not virtual, it's not a video game. It's real."

Sargent developed a prototype for what is now the GigaPan system. Users punch numbers into a keypad on a robotic mount for a digital camera, specifying how expansive they want their panorama to be. A microprocessor calculates the size and number of exposures needed for the pan and moves the camera accordingly. A small robotic finger pushes the shutter button for each exposure. These are stitched together to form a panorama with a resolution 1000 times that of HDTV. The largest GigaPan has 100 gigapixels.

The final image contains more data than most personal computers can handle, so Nourbakhsh and his team developed a massive server system and Web site, www.gigapan.org, for storing and accessing GigaPans. When viewers zoom in on an area of an image, they seem to fly into the image itself. The result is an immersive, interactive experience that can reveal surprising details—an ant on a leaf in a forest, or a hummingbird sipping nectar from a flower in a backyard. It's like viewing nature through a huge magnifying glass.

Sargent, who now has a joint appointment at NASA Ames and CMU, and Nourbakhsh, head of CMU's CREATE Lab, founded GigaPan Systems LLC in 2008 to manufacture and sell the systems at close to cost ($299 to $895). They are continuing to develop technology for creating and viewing high-resolution scans as co–principal investigators of the Global Connection Project, a joint development between NASA Ames, the CREATE lab, Google Inc., and the National Geographic Society.

Gigapixel science

GigaPans have captured the public's imagination. Five thousand systems have been bought, and today the site hosts 40,000 public panoramas that draw 20 million visitors a year; another 20,000 are in private areas of the site while contributors work on them. Sargent and Nourbakhsh began training scientists to shoot GigaPans in 2008, and some 120 investigators

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CREDITS (LEFT TO RIGHT): M. ALEX SMITH, UNIVERSITY OF GUELPH; GENE COOPER, FOUR CHAMBERS STUDIO, SPECIMEN COURTESY OF JOHN RAWLINS, CARNEGIE MUSEUM OF NATURAL HISTORY

Fine details. Snails in an urban forest and the texture of a beetle's carapace show the power of GigaPans to home in on details.

are now using the system in their research. In mid-November, scientists will share findings at the Fine International Conference on Gigapixel Imaging for Science, hosted by CMU and the CREATE lab.

Paleontologist K. Christopher Beard and archaeologist Sandra Olsen of the Carnegie Museum of Natural History in Pittsburgh and photographer Richard T. Bryant trained their GigaPan on remote Saudi Arabian petroglyphs, including the Eagle's Nest in Juba. The engravings date back to the Holocene Wet Phase (9000 B.C.E.–5000 B.C.E.) when the environment resembled that of today's African savanna, and lions, gazelles, cheetahs, wild asses, and hyenas roamed the land. Camel drawings accompanied by writing appeared in 1500 B.C.E, followed by images of horses and chariots. "You can see grains of sand, details of grooves and peckings, and the relationships between the images, which is important for dating," marvels Olsen, who runs the museum's anthropology section. The technology reduces the time spent on expensive on-site research. "We can be there briefly producing GigaPans, take that data home, and study images at our leisure on a wide-screen computer," Olsen says.

Online
sciencemag.org
The online version of this article links to the highlighted GigaPans.

The technology also lets Olsen share data easily with colleagues and peer reviewers. "This is the closest to being there," says Olsen. Such data sharing lets colleagues perform the same kind of analysis she does, and below her panorama they can post details they found and annotate them.

M. Alex Smith, a molecular ecologist at the University of Guelph in Canada, is deploying the technology closer to home. He is using GigaPans to monitor the "Dairy Bush," an urban forest that has been part of the Guelph campus since 1830. The 8.5-hectare wood lot contains rare and listed species, but this living laboratory for ecology students has degraded as its surroundings changed from farmland to condos and shops, and invasive species gained a foothold. To monitor such pressures, Smith abandoned the rough, "Victorian method of pencil and paper" for the GigaPan's precision. Since August 2009 he has taken weekly shots from the same location, which enabled him to discover phenomena and return with questions he had not known to ask. "There's a chokecherry on the lower left quarter of the pan full of insects from spring to fall that I wasn't seeing," he says, "and assassin bugs and parasitic wasps I wasn't aware of." Users worldwide have discerned, grabbed, and sent shots of snails, caterpillars, and trash.

Smith has also produced a time-lapse video of his series of pans, now on YouTube. The video helped him study the formation of the Dairy Bush tree canopy, which is critical to quantifying a forest's response to climate change. Time-lapse video is not zoomable now, but at the November conference Sargent and Nourbakhsh will unveil a viewer that will let users zoom and move back and forth in time.

For John Rawlins, curator of invertebrate zoology at the Carnegie Museum of Natural History, the GigaPan is an opportunity to archive and share a 17-million-bug collection. The advantage of "pixel traveling" is "scary in a way," Rawlins says, because the staggering sharpness reveals minutiae—spinules (thorny spikes) on legs or the microsculpture of forewings, for example—that can easily be missed while examining a bug under a microscope. Rawlins forecasts that such detailed and accessible archives will allow researchers to identify insects rapidly using automated image analysis and pattern searching.

With that goal in mind, Rawlins is collaborating with Gene Cooper, president of Four Chambers Studio in Vallejo, California, and CMU to develop a microGigaPan using an optical microscope. One effort involves imaging a Powdermill butterfly from the 1950s. Rather than compare two side-by-side photographs of its front and back, this system makes possible simultaneous inspection through pixel layers of varying transparency, so the viewer can evaluate wing markings as if passing through the insect. And the next step beyond microGigaPans is coming soon: nanoGigaPans, with as high as 8000 times magnification (0.01 gigapixels). NASA Ames's Jay Longson and Rich Gibson have adapted scanning electron microscopes to produce extreme close-up pans of insects, cells, and seeds.

There are drawbacks to the technology. It can take hours to shoot sections of a pan and stitch them together, for example, and sometimes the stitching software has trouble matching uniform patches, like sky. And Nourbakhsh is concerned that his team has created yet another technology that enables people to spend all their time exploring on their computers instead of experiencing the world firsthand. But from martian vistas to cellular landscapes, GigaPans are putting science in the picture in interesting new ways. Some day a picture may well be worth 1000 gigapixels.

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