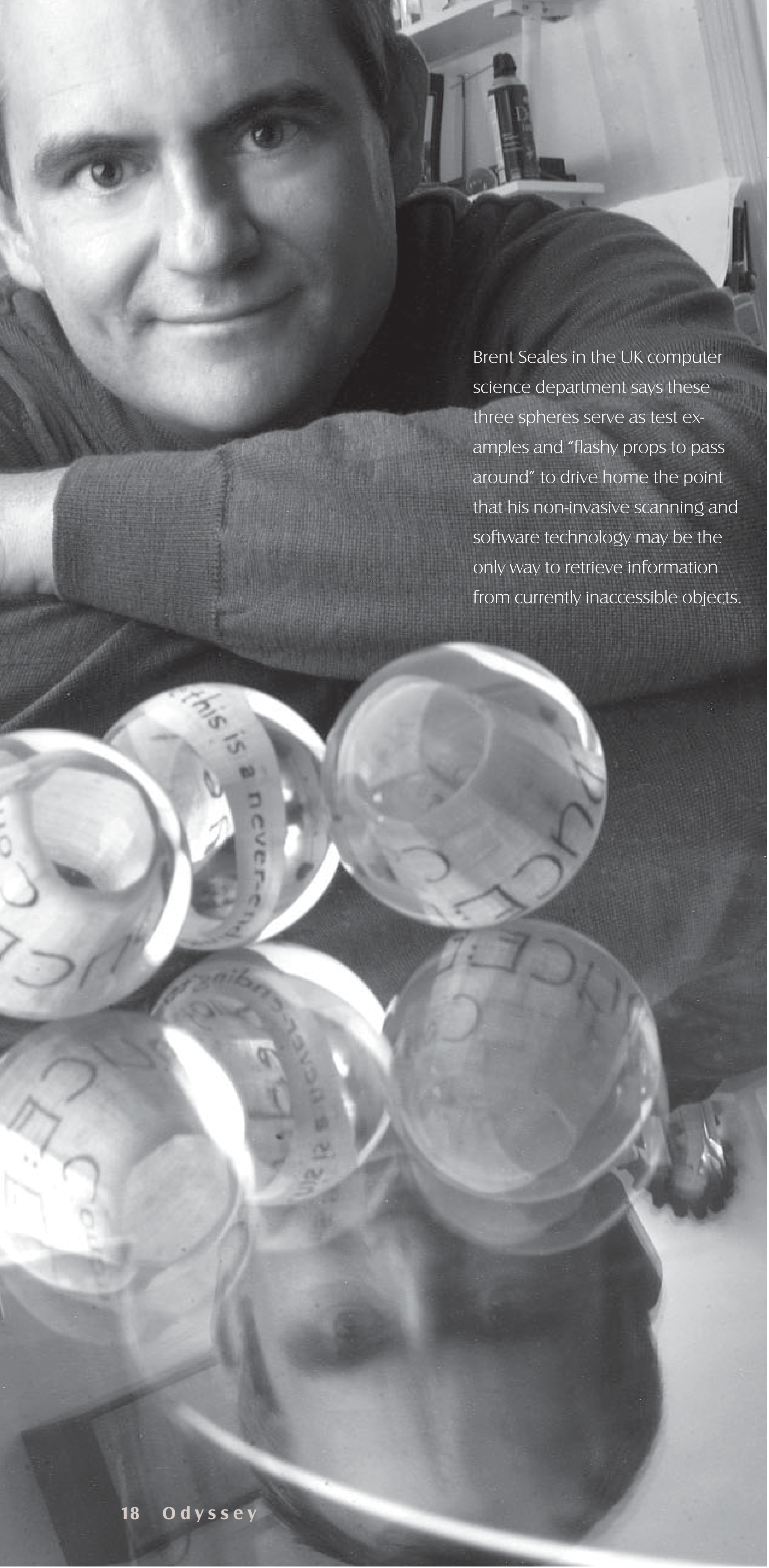


Brent Seales in the UK computer science department says these three spheres serve as test examples and "flashy props to pass around" to drive home the point that his non-invasive scanning and software technology may be the only way to retrieve information from currently inaccessible objects.

Digital

"My precious," he hisses, doing his best impression of Gollum, the creature from Tolkien's *Lord of the Rings*. The phrase alludes to the mythical quality of an object his grad students have dubbed "The Glowing Orb of Life."

Brent Seales laughs as he cups in his hand the clear polyurethane sphere, roughly two inches across. Embedded inside is a curious strip of paper.

"It's called a Möbius band. Have you heard of it?" he asks as I reach for the sphere. Seales explains that before this strip of paper was entombed, he put a half twist in it, then connected the ends together. "You could trace around the whole strip without ever lifting your finger off the surface."

I spin this oddity to follow the inked message on the strip of paper: "It is a never-ending text and

Exploration: Unwrapping the Secrets of Damaged Manuscripts

WRITTEN BY
Alicia P. Gregory

by educing its secret you must now read it forever because it is a never-ending text…."

The project for which this sphere and three others were created is called EDUCE, which stands for Enhanced Digital Unwrapping for Conservation and Exploration. (Seales has a habit of naming his projects so that the acronym spells something clever. The etymology even makes sense: in Latin *educere* means "to bring out.")

And indeed, his goal is to educe the secrets of damaged manuscripts and artifacts. "This is my version of exploration," says Seales, an associate professor who's been in the UK computer science department since 1992. "It's like digging for gold. You don't know what you're going to find. This," he pauses, searching for the words to round out his analogy, "is actually prospecting for information that nobody's seen."

But unlike the prospectors of the American West with their picks and pans, Seales's tools of the trade are a specialized CT scanner and proprietary imaging software, and his objective is to "unearth" secrets for the world's scholars. And the spheres serve as test examples (and "flashy props to pass around") to drive home the point that such non-invasive scanning and software technology may be the only way to retrieve information from currently inaccessible objects.

Seales and his team spent a year developing software that could digitally flatten a damaged manuscript, say one rumpled by hundreds of years of moisture, so in 2000 Seales went to the British Library in London to try his technique out on the real thing.

At the time he was the principal investigator of a three-year, NSF-funded project called the Digital Atheneum. The project's goal was to develop new techniques for restoring, searching and editing humanities collections.

In the bowels of the British Library, the first object the conservator showed Seales was a manuscript that was so mangled, he says, "We almost ran screaming from the room, because there was nothing we could do. We had no tools that could help."

Seales tells me such manuscript fragments exist in the nooks and crannies of almost every archive. "Exactly how many? It's hard to tell," he says. "In the old days, these kinds of manuscripts were cracked open and pains-

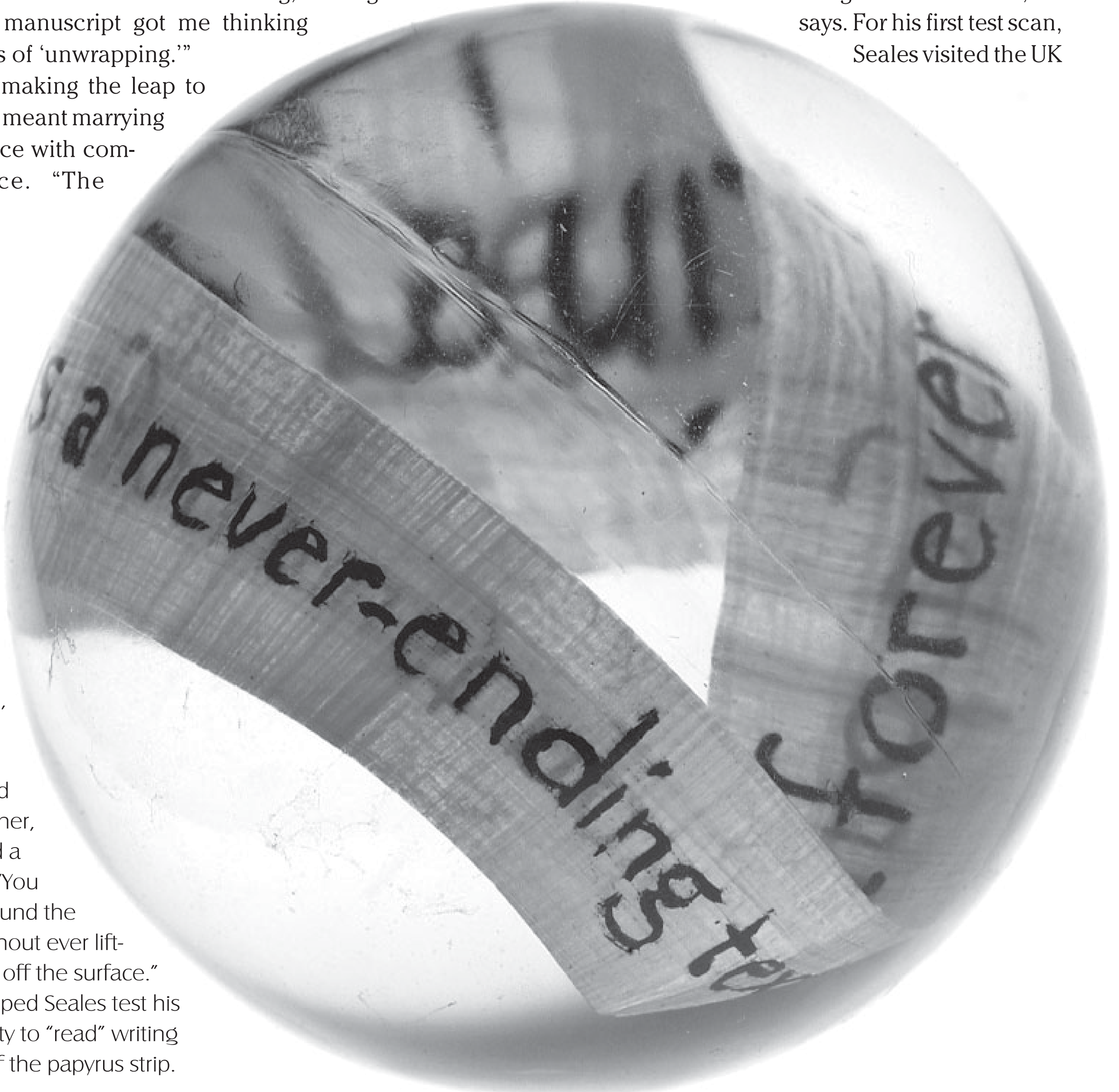
takingly laid out on paper with tweezers and a magnifying glass. Libraries stopped doing that with all of these damaged objects because they didn't have the manpower to do it, and they weren't getting the results they wanted."

Seales becomes more animated as he tells me that the conflicted feelings conservators have about manuscripts—"You'd like to know if anything's there, but it just doesn't feel right to destroy it"—motivated him to create a non-invasive exploration tool.

After their encounter with the mangled manuscript, Seales says, "Instead of virtual 'flattening,' seeing that beyond-hope manuscript got me thinking along the lines of 'unwrapping.'"

For Seales, making the leap to "unwrapping" meant marrying medical science with computer science. "The whole idea is that you can't expose parts of the object that you need to see because they're buried. We've been using a CT—computed tomography—scanner, because we need penetrating technology," he explains. CT scanners, which doctors often use to detect tumors, simultaneously send out several X-ray beams from different angles to capture a "slice." "Then the whole apparatus shifts by a microscopic amount and you take another slice," Seales explains. His software puts these slices together ultimately to form a cross-sectional, 3-D picture.

But your run-of-the-mill CT scanner isn't ideal because it wasn't designed to read text, he says. For his first test scan, Seales visited the UK



Before this strip of paper was entombed, Seales put a half twist in it, then connected the ends together, in what's called a Möbius band. "You could trace around the whole strip without ever lifting your finger off the surface." This sphere helped Seales test his software's ability to "read" writing on two sides of the papyrus strip.

hospital. He wrote the words "UK 2003" on a piece of paper, rolled it up and put it in the scanner. "The CT operator thought I was nuts," he says, laughing. "They're used to looking for fissures or bubbles, not writing."

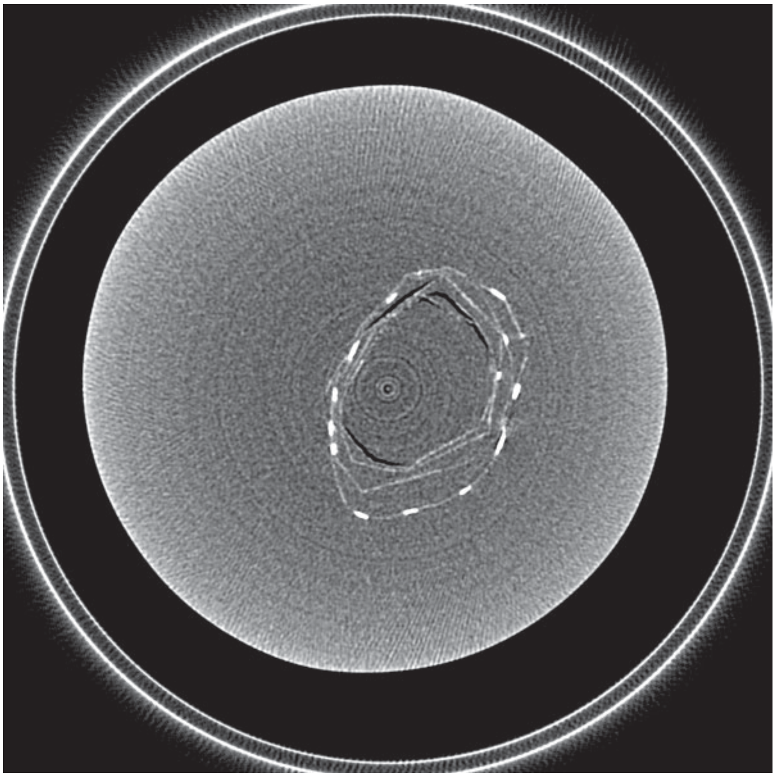
He says if you think about reading text (seeing something that's only as thick as a piece of paper), you need really good resolution. Medical imaging doesn't require that kind of resolution, but Seales discovered that scanners built for manufacturing analysis were just the ticket.

And he found a partner in physicist Joseph Gray at Iowa State University's Center for Nondestructive Evaluation. Gray's custom-built scanner, Seales tells me, is driven by a cluster of computers because it takes so much computational muscle to do the scan. The scanner was created for the express purpose of using non-destructive means to check manufacturing processes, for instance, to determine the integrity of a hypodermic needle.

"The beauty of this scanner is its resolution capabilities," Seales says. "Medical scanners have a fixed 'ring size.' The resolution of each slice is determined by how many pixels are spread out over the size of that ring. If the ring is big enough to fit your entire body into and the resolution is, say, 512 by 512 pixels, if you put just your little finger in there, the scan would get about 10 pixels on your finger's cross section, and the rest of the pixels would sample the air around your finger. With Joe's scanner, we can move that ring down to a very small size so that the 512 by 512 pixels are 'focused' exactly on your finger and we could get 500 slices between the first and second joints.

"We needed a scanner that can be adjusted to 'artifact-size,' not fixed at 'human-torso-size.'"

A. A photo of the text Brent Seales wrote on a papyrus strip before it was embedded inside a polyurethane sphere

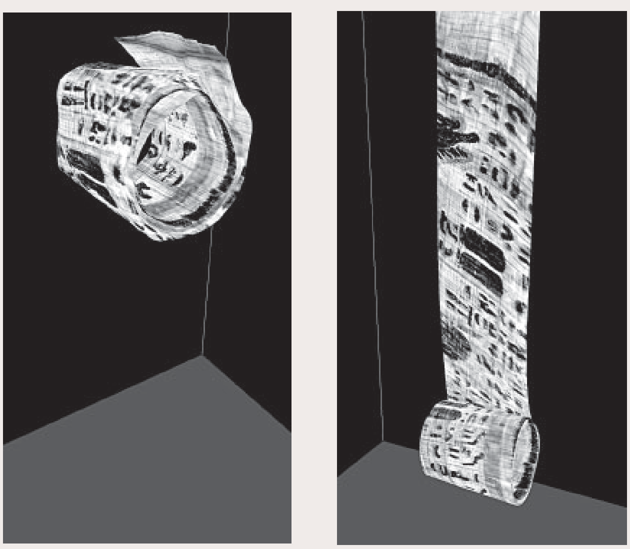


B. In this CT slice, the white "flare-ups" indicate where ink is on the papyrus strip.

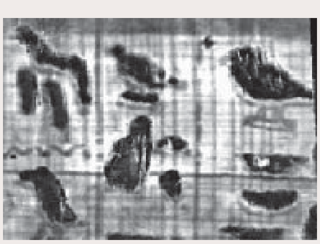
C. The virtual strip unrolled by the software

A. Joseph Gray took this photo of a replica Egyptian papyrus scroll, the kind of thing you can buy in a museum gift shop, before he scanned it with his custom-built CT scanner.

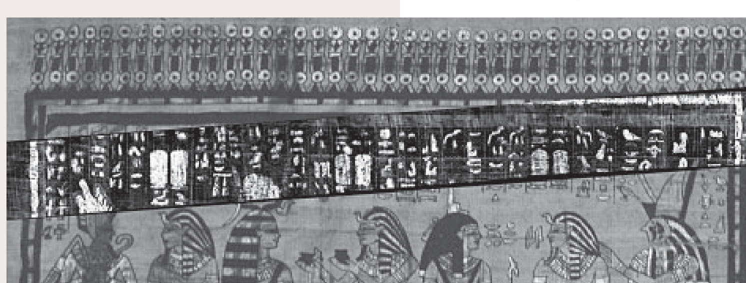
B. This CT slice from Gray's scanner shows the flare-up of ink (the white regions).



C and D. After Brent Seales's software puts the CT slices together, it "unrolls" the virtual scroll.



E. A close-up of the virtual scroll after passing through the software shows the detail captured by the CT scanner.



F. The virtual scroll strip is inset over the photo of the original scroll.

The biggest challenge to capturing all of this information is dealing with file size. "At 50 micron resolution, we take 1,000 slices. Our data sets are easily 2 to 3 gigabytes. You can't just load that up on a PC."

But what happens after you get all of this data? Seales says his software (based on very complex algorithms) puts all of the slices together, then allows you to grab the top edge with the mouse and apply "gravity" to unroll the object and "push" it against a virtual wall to flatten it out.

For the first test of Gray's scanner, Seales purchased a sheet of papyrus at an art store, along with several colors of ink. He cut the sheet into a strip, drew circles, squares, triangles, and numbers on it, then rolled it up and had Gray scan it. "We could get all of the fibers of the papyrus to come out great, but at that first power setting we couldn't see the ink. At a different setting, the ink came out great, but the papyrus was just a white blob with no detail. We realized it would take a little trial and error to find the right setting for each object."

For their second test, Gray used something he found lying around his house—a replica Egyptian papyrus scroll, the kind of thing you can buy in a museum gift shop. He rolled it up and scanned it. [See photos on this page.] "It was exciting to see the birds materialize as the software slowly unrolled the scroll," Seales says. "But I never even saw the actual scroll. So I decided the next object we scanned needed to be something I could pass around, to show 'before' and 'after.'"

So why did Seales commission a sculptor to create the "Glowing Orbs of Life"? He needed scientific objectivity.

"When I did our first sample, with the circles and numbers, I carefully rolled up the strip and made sure the layers weren't touching to ensure the software could distinguish one layer from another. And that's fine for the first time, but after that I realized I can't do this because I'm going to engineer it so it works," he says. "I wanted to give control over to someone else, so I couldn't contrive the way it would turn out. And that's more like it's going to be when we eventually work with real objects. It's going to be very random."

Tim Vetters, a sculptor who works for a foundry just outside Lexington, twisted and rolled strips of papyrus in a variety of ways (wrapping some as many as five times). He suspended the papyrus, poured liquid polyurethane into a spherical mold, let it harden, and took the spheres to UK. "We got the first sphere back from Tim; we sent it to Joe, who scanned it and sent the data back to us. We spent a month tweaking our algorithms to make it unroll correctly," Seales says.

Building that randomness into his tests was Seales's first reason to create the spheres. The second was that "a tangible example is a powerful thing. It's a flashy prop I can pass around," says Seales, noting that's invaluable in his sales pitch. "This project will go nowhere if I can't get the partnerships I need from the scholars who have access to real objects. I've moved into high gear to make that pitch."

He's presented his software and spheres to a variety of groups: the Joint Conference on Digital Libraries (put on by the Institute of Electrical and Electronics Engineers and the Association for Computing Machinery), and annual meetings of the American Library Association and the Society of American Archivists.

People who go to technical conferences tend to be jaded, Seales says. They've seen it all. "It's hard to impress them, and even if you do, they rarely show it." But when he showed his digital demo of a papyrus scroll unrolling at the Society of American Archivists conference in Beverly Hills in fall 2003, the crowd gave him the most positive reaction imaginable. "With the knowledge of what they have in their collections, when these archivists saw me, before their eyes, unroll this scroll there was literally an 'AHHHHH!'" A warm-and-fuzzy feeling wasn't all Seales got from that experience. He also earned a nickname from his colleagues: "Now they call me 'Audible Gasp.'"

Seales says he's trying to pick up some high-profile partners in addition to his senior collaborators on EDUCE: Kevin Donohue (UK electrical and computer engineering), Jim Griffioen and Ken Calvert (UK computer science), Joseph Gray, Paul Mostert (professor emeritus, University of Kansas), Duncan Clarke (Fremont Associates, South Carolina), David Jacobs (British Library), and Chris Collins (Natural History Museum, London).

The EDUCE team, with Seales as principle investigator, is currently working on a proposal to the National Science Foundation that would take this work to the next level, paying for travel and staff time to scan and digitally unroll real-life objects.

"We actually envision building a software tool to allow curators, conservators and scholars to do the analysis on their own, because they know what they're looking for and if what they see means something. Our role would be maintaining all the technology underneath." ■