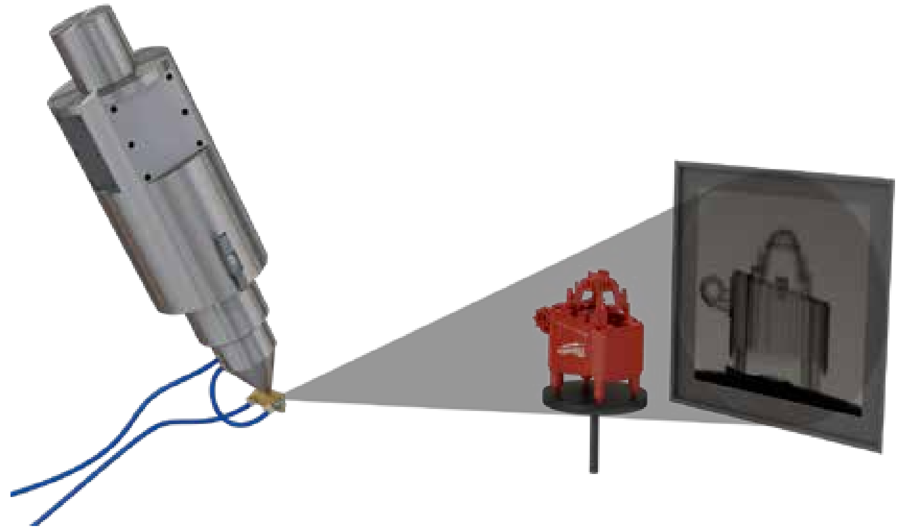
New knowledge from ancient specimens using X-ray Computed Tomography (CT)

X-ray Computed Tomography (CT) at the Smithsonian Institution's National Museum of Natural History is delivering new knowledge from ancient specimens

The mission of the Smithsonian Institution, the world's largest museum and research complex, is admirably brief: "The increase and diffusion of knowledge." The vision statement, a bit longer, is no less cogent: "Shaping the future by preserving our heritage, discovering new knowledge, and sharing our resources with the world." Within those statements is a commitment to finding and using the most effective tools to accomplish these ideals. The following describes how the Smithsonian's Natural History Museum together with an engineering consulting firm known mainly for ballistics and armor testing are using X-ray computed tomography (micro CT) to not only scan marine mammal fossils, but also make 3D scans and all the data they contain available for knowledge-seekers around the world.

The consulting lab is Chesapeake Testing in Belcamp, MD. Founded in 2006 by Jim Foulk, Chesapeake Testing was originally envisioned as a ballistic testing laboratory. "We saw a big uptick in the research and development of armors, with trying to get lighter weights, better performance," Foulk says. "These different manufacturers who have a new, better idea would like to get it tested before they submit for testing by the government."

Essentially, our quest to understand armor led us to acquire some unique complimentary capabilities," adds Chris Peitsch, lead NDT engineer. "It's these capabilities, such as CT scanning, that allowed us to diversify our business very easily." To expand its suite of testing equipment, Chesapeake Testing began researching X-ray system suppliers and began working with Nikon Metrology (with North American headquarters in Brighton, MI). It quickly zeroed in on Nikon Metrology's



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largest offering, a combined 225/450kV microfocus X-ray and computed tomography system. The system's powerful source, walk-in bay, and panel shift capability allow Chesapeake Testing the versatility to inspect larger components that typical cabinet CT systems are unable to accommodate. This large-scale system gives Chesapeake Testing the capability to image large objects up to 37 inches in diameter.

Non-destructive testing with X-ray micro CT continues to make inroads into quantifying and improving components in many vital and essential industries such as aerospace, automotive, medical, and many others. This is mainly due to micro CT's ability to inspect and measure internal and external component surfaces and even produce component slices that yield significant information without destroying the part. These are the same attributes driving it into new frontiers, one of the most exciting being the scanning of marine mammal fossils at the Smithsonian Institution's National Museum of Natural History.

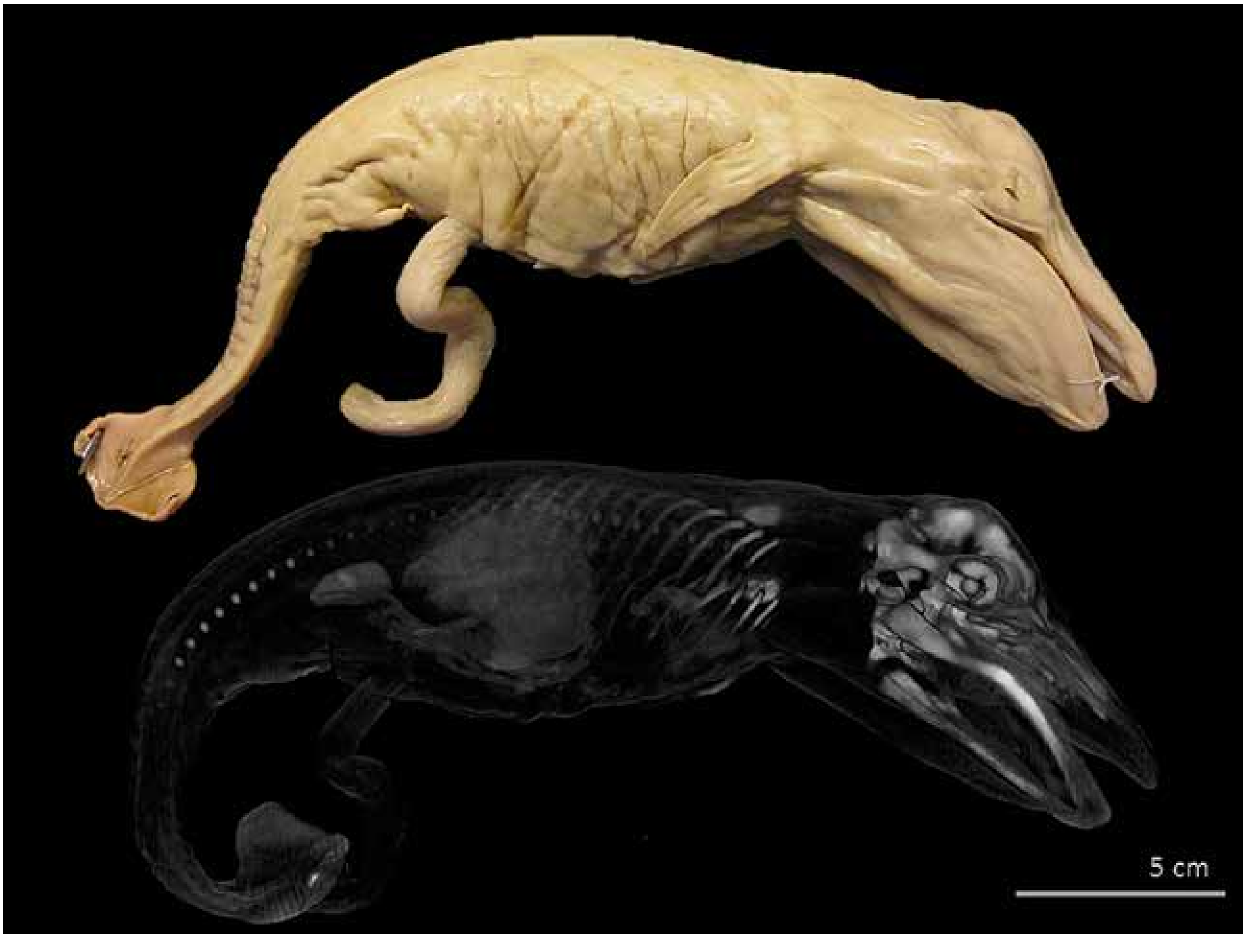
"I'm a paleontologist, and what I'm really interested in is how evolution works," says Nick Pyenson, Ph.D., curator of marine mammal fossils at the Smithsonian Institution's National Museum of Natural History (NMNH). "How does the fossil record show us what happened in the past and how the world has shaped that since? Climate change is a critical issue right now, and mass extinction events in the past point to similar events going on in our lifetime. The fossil record comes to bear more importantly than ever before."

Pyenson has published research using CT data for more than 10 years, all in an effort to understand the big picture of how four-limbed marine mammals such as whales descended from land-based tetrapods and how the return to the sea over time changed their anatomy (legs into fins, for example). "Across 250 million years, many land-based vertebrates returned to the sea, and the CT scans help us see some of the resulting solutions." Another is colleague Dr. Maya Yamato's work on CT scanning fetal whale specimens from the NMNH's collection to model the development of how whales hear.

What X-rays Reveal

Computed tomography is essentially the coupling of ever-increasing computing processing power with X-ray technology and digital photography. A fundamental setup includes the X-ray source, the object being measured, and a detector. A rotating platform for the object being imaged helps keep the subject in the field of view while penetrating the sample from all angles.

A single micro CT session with a single sample can produce thousands of digital images. Each two-dimensional pixel in each image can become a three-dimensional voxel as computer algorithms reconstruct 3D volumes. With 3000 images, for example, a billion or so voxels are produced, and each is processed 3000 times. The result is a 3-D volumetric map of the object, where each voxel is a 3-D cube with a discrete location (x,y,z) and a density (ρ). Not only is the external surface information known, such as with a 3-D point cloud from laser scanning, but internal surfaces and additional information



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about what is in between the surfaces from the fourth dimension (density) is provided.

"We have a mission to expand and commercialize applications for micro CT," says Peitsch. "We hope the work with the Smithsonian will open some eyes. The fossils really pushed the envelope of our capabilities, both in size and resolution. Some samples were up to three feet in diameter and one or two feet thick, and most were scanned at our 450 kV microfocus capability. It's very interesting how the work we're doing with the fossils correlate with industrial work we're doing in composites, among other industrial areas. The interconnects are fascinating. It's an ongoing way of looking at things differently.

"The 3D imaging capability of Chesapeake Testing's equipment is really kicking it up a notch," Pyenson says. In addition, sharing 3D models along with all the attendant data is "really a disruptive mandate" he adds. Pyenson and the Smithsonian are using a number of digital tools: 3D printing to make copies of valuable originals; 3D web platforms (3d.si.edu) for downloading CT and other digital scans, and the CT scans themselves. "Nothing replaces the original, but with micro CT you get surface and internal structures that will definitely further research," Pyenson says. "It's the middle schoolers that will get the most out of this from artistic and creative standpoints as well as scientific. We cannot foresee the impact of this technology."