THE *NUCLEAR NEWS* INTERVIEW

Howie Choset: Snake robots

An innovative tool for infrastructure inspection may soon be slithering its way through nuclear power plants.

Choset: "There is really nothing that can go into small tubes or pipes the way our robot can."

Robotics professor Howie Choset has always been fascinated by movement. "Whether it's cars, people, mechanisms—I find all kinds of motion interesting, and I have for as long as I can remember," he says. "And that creates an affinity for robotics, because what you're essentially doing in robotics is designing, creating, and controlling motion." It's an interest of Choset's that extends to the animal world as well, exemplified by his work as director of the Biorobotics Laboratory at Carnegie Mellon University's Robotics Institute, where he has created a comprehensive program for the development of robots that mimic the movement of snakes.

Choset, who was selected by the *MIT Technology Review* in 2002 as one of the world's top 100 young innovators, sees applications for his snake robots in a variety of fields, including search and rescue, manufacturing, surgery (he is a cofounder of Medrobotics, a company that makes a small snake robot for use in minimally invasive surgery), and infrastructure inspection. Earlier this year, one of his robots underwent testing at a nonoperational nuclear plant in Zwentendorf, Austria, in order to gauge the technology's value as an inspection tool for nuclear facilities.

Choset, who holds a Ph.D. in mechanical engineering from the California Institute of Technology, recently spoke about his work and the testing of his device at the Zwentendorf plant with *NN* Associate Editor Michael McQueen. (Photos: Carnegie Mellon University)

When did you first become actively involved in robotics?

I started building little toy motorized cars when I was in elementary school. I built some basic robots—little mobile robots—when I was in high school. I entered a couple of science contests—this was before they began to hold all these robot competitions. I remember being a finalist in the Long Island Science Congress competition.

Can you provide a little history on the snake robot concept?

The first person to design a snake robot was Prof. Shigeo Hirose in Japan. He is an amazing researcher and, without a doubt, a pioneer in the robotics field. He has done many things, but his early work was on snake robots. He built the first one in 1971, and he was really the only game in town until 1990, when my academic advisor at Caltech, Joel Burdick, along with Greg Chirikjian, his student at the time and now a colleague of mine, built the first snake robot in the United States. Joel and Greg have since moved on to other things, but their research inspired a lot of other people's work, including mine.

How long have you been working on the snake robot concept?

I've been working on it for 17 years, but the current robot, the one that was tested at the nuclear plant, is only three or four years old.

While it's apt, I'm guessing that "snake robot" may not be the technical term for the device?

It's also called a "hyper-redundant mechanism," but few people use that term. I think it's a great term, by the way. My colleague Greg Chirikjian coined it. The idea behind the term is that if you're extra, you're re-

CMU mechanical engineering Ph.D. student Chaohui Gong deploys the Biorobotics Lab's snake robot into the Zwentendorf nuclear power plant's turbine room steam piping through a spherical vessel.

dundant. And snake robots have lots of extra degrees of freedom, so that's why they're called hyper-redundant. There are many kinds of hyper-redundant mechanisms. In addition to the locomoting snake robots that interact with the environment to move forward like a snake, there are also fixed-base robots, similar to an elephant trunk that probes and pokes around. Sometimes we call those "trunk bots," but really, I call them all snake robots. And that's the term that has really gained popularity.

Of course, one of the reasons you might want a locomoting snake robot as opposed to a fixed-base mechanism is that with a fixed base, you can reach only as far as the length your mechanism allows. With a locomoting snake robot, you can really go a great distance.

How would you describe the snake robot that was deployed at the Zwentendorf plant?

It's a locomoting snake robot, 2 inches in diameter, 37 inches long, and multijointed. It has 16 degrees of freedom—16 points of articulation. It's able to exploit its shape and those degrees of freedom to thread through tightly packed volumes and get to positions and locations that conventional machinery cannot.

Would you describe the device as a prototype?

Yes. It's still in its prototype stage. But for a prototype, it's very, very well hardened.

Is there any thought about when you would consider it a commercially viable product?

As with anything, transitioning from prototype to commercial product is a matter of investment, and if I can get that investment, I can start making that robot into a commercial product within 12 to 18 months. I'm excited that you're writing an article about this for *Nuclear News* because hopefully I'll

CMU robotics Ph.D. student Matthew Tesch inserts the snake robot into the piping of the Zwentendorf plant.

be able to inspire some people out there to want to use this technology.

The other kinds of robots used for similar inspection purposes are usually wheeled or have legs, correct?

It depends on the application. But if you're thinking about going into nuclear power plants, other robots can go into only really big pipes, big tubes. There is really nothing that can go into small tubes or pipes the way our robot can.

So the robot is actually going inside the tubes or pipes?

Oh, yes. The robot can climb inside pipes as well as outside. There are videos on my website [<www.biorobotics.org>] that show that.

Is the video camera that is mounted at the end of the device a conventional camera?

The camera itself is a normal camera. However, my colleagues Christoph Mertz and Martial Hebert and I built an integrated camera head that has a built-in laser rangefinder to give us both visual and range/depth information.

And the camera also has something called a "right side up" feature?

Yes. There are accelerometers on board, so we can infer which way is up and which way is down, and from there we can right the image, making control of the robot more intuitive.

How is the robot controlled?

A joystick can be used to control the robot. However, there is a lot of autonomy going on to coordinate the internal degrees of freedom to make the robot move.

How many people are involved in controlling the device?

Right now there are two, but ultimately there will be one person driving the robot.

Why was the Zwentendorf nuclear plant selected for the test?

One of my students is from Austria, and he knew the people there. The plant never operated because the Austrians voted not to let it start up. Its lack of radioactive contamination makes it suitable for training and research.

How long was the test at the plant, and what were the results?

It was a two-day trial. We wowed the inspector.

What would you say are the specific nuclear applications for the snake robot?

In general, I would say going through non-piggable lines and narrow pipes, getting into boilers and pressure vessels without having to take anything apart. The snake robot can go up and around multiple bends, something you can't do with a conventional borescope, a flexible tube that can only be pushed through a pipe like a wet noodle.

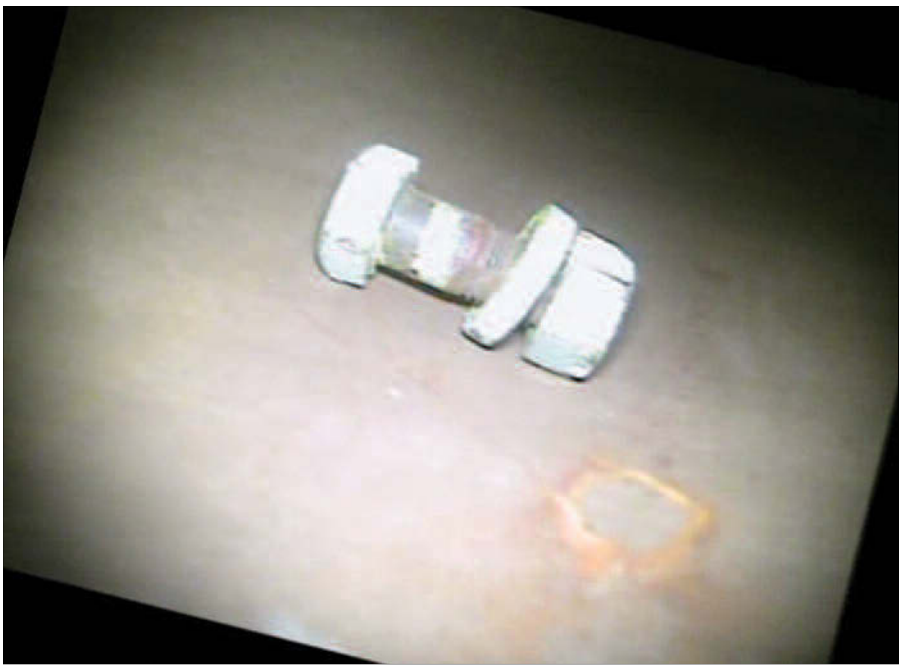
Are there any future improvements planned for the robot—things you'd like to be able to do with it that you cannot do now?

We want to give the robot a better situational awareness. We want to be able to put additional sensors on the robot and develop the algorithms that will allow it to have a better three-dimensional understanding of its remote environment. It should be able to map the pipes so that you have a 3-D model of the pipe when you're done. We want to be able to make the system a little more modular so that we can snap different kinds of modules in and onto the robot. We want to be able to make it smaller in the future. We want to be able to make it move faster. I could go on and on. But the real limitation for us is finding the financial support to do the work.

Is there anything you would like to add?

In addition to the inspection application, another area of interest that is very near and dear to my heart is search and rescue. A lot of the technology we're developing will have a dual use for search and rescue applications. NN

In a demonstration of its climbing capabilities, the snake robot climbs a cable at the Zwentendorf plant.



A bolt inside a pipe, as seen through video returned by the snake robot.