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Robotics Trends

The business guide for professionals who use, manage, or create robots and intelligent systems

Mining the Seafloor with Robots

Gold, rare earth elements, and other sea riches could sustain humanity for centuries, while providing enormous opportunities for robotics developers.

By Emmet Cole

With land-based mineral deposits beginning to run out and the cost of precious-metals extraction on the rise, large mining companies—and even nation states—are racing to the bottom of the sea in an attempt to exploit the incalculable mineral resources of the world's oceans.

At the forefront of this effort are robots, in the form of specialized remotely operated vehicles (ROVs). But it's a race filled with uncertainty. No one knows the exact quantity of the precious metals. Indeed, to date, no one has mined the oceans for precious metals at depths greater than 200 meters, and licenses for exploration and mining remain hard to come by.

The first targets for competitors with deep-ocean-mining plans on the drawing board are so-called polymetallic sulfides, which are rich concentrations of precious metals including gold, silver, copper, and zinc, found around volcanic vents on the seabed. No one has successfully utilized equipment for mining these metals at such depths at any scale, let alone developed specialized ocean-mining ROVs capable of sustained operation in limited visibility, high-pressure environments where these vents are found.

Yet another prize on the ocean bottom are deposits of rare earth elements, which are essential to the production of magnets within electric cars and windmills, as well as the components of computers and other devices the world has come to depend on. With virtually all of the earth's supply of rare earths currently controlled by China, nations and large corporations are scouring the planet for alternate sources. As with the precious metals found in the vicinity of volcanic vents, experts are not certain if undersea rare earth deposits can be mined economically.

These challenges aren't stopping several companies from mounting ambitious plans for undersea-mining expeditions. In January, two of the world's biggest mining companies, AngloGold Ashanti and De Beers, announced a four-year, $40 million

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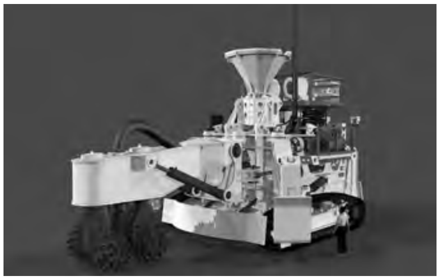


The 250-tonne auxiliary cutter will clear the way for the other ROVs to operate. (All images in this article courtesy Nautilus Minerals and SMD.)

The bulk cutter ROV is designed to segregate material collected from the seafloor.

joint venture to prospect for gold deposits off South Africa's coast. In the same month, Japanese daily *Yomiuri Shimbun* reported that the state-backed Japan Oil, Gas, and Metals National Corp. has plans to deploy remote-controlled robots at depths of up to 2,000 meters to mine rare earths and precious metals on the ocean floors around Japan's coasts. The $360 million project will focus on seabed volcanoes near the Izu and Ogasawara island chain south of Tokyo and is expected to begin production within the next 10 years. Japan is estimated to have underwater resources worth in excess of $2.3 trillion.

Meanwhile, the Korea Ocean Research & Development Institute (KORDI) has developed an autonomous robot called MineRo that is designed for ocean-floor exploration and deep-sea mineral deposit mining. KORDI claims that the 9.6-metric-tonne, tracked robot vehicle is capable of mining 8.6 tonnes of material per hour. Following a series of successful pilot-scale tests spread over two years, KORDI transferred the MineRo technology to Hanhwa Corp., one of South Korea's largest industrial engineering companies, in late 2010 for a royalty of around $6.5 billion.

Machines for the Cold, Dark Depths

But the undisputed current leader of the race to mine the world's oceans is Toronto-based mining company Nautilus Minerals Inc. In January, the company won a 20-year lease from the government of Papua New Guinea to mine a site known as Solwara 1, located about 30 kilometers off the equatorial island's sparsely developed coast and 1,600 meters below the ocean surface. Actual mining at Solwara 1 is expected to commence by the end of 2013, making it the world's first oceanic precious-metal mine.

The project is "revolutionary, in the sense that no one has mined for copper, gold, silver, and zinc at depths of 1,600 meters," but the technology has some precedence, says Joe Dowling, vice president of investor relations and communications at Nautilus. "The oil and gas industry has been developing ocean-based oil platforms and gas platforms since the 1940s, and diamonds have been mined off the coast of Namibia, at depths of 200 or 300 meters, for the best part of 20 years. What we're doing is adapting existing technology that's been used in those industries for our purposes," explains Dowling.

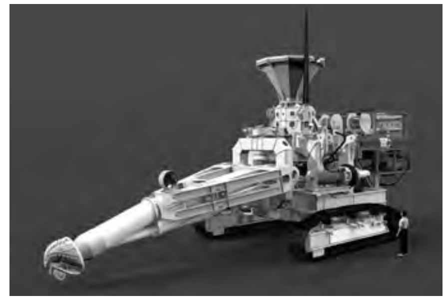
Nautilus has amassed some impressive equipment to create what the company calls its "seafloor production system." The first ROV to descend to the ocean bottom will be the 250-tonne auxiliary cutter. This ROV is designed to level the undersea terrain, using counter-rotating cutting heads. The process is intended to create a working space for the next ROV to arrive—Nautilus' bulk cutter.

The bulk cutter has a drum fitted on the front, and is designed to carry out the bulk production process, which involves separating out material for further processing. When the bulk cutter finishes its work, the final piece of equipment, a collecting machine, is deployed. Dowling describes it as "a big vacuum cleaner," which pumps the material in slurry form up to a ship.

The undisputed current leader of the race to mine the world's oceans is Toronto-based mining company Nautilus Minerals Inc.

The equipment is lowered to the ocean floor using heavy-duty lift lines, similar to those used to lower materials down shafts in terrestrial underground mines. Control and power are supplied via multiple conductors and fiber-optic lines encased in an armored umbilical between the vessel and the robot. Meanwhile, cameras and 3-D sonar arrays are used to map each machine's position, with this information being passed through the umbilical to a human operator on the surface. The operator has joysticks and multiple control and diagnostic screens to help manage the ROV's operations. Landing and liftoff is a delicate process, with the operator paying particular attention to the ocean swells during these maneuverings.

The system, which is being built by Newcastle, U.K.-based remote intervention equipment company Soil Machine Dynamics Ltd. (SMD), differs in basic ways from conventional land-based mining equipment, according to Stef Kapusniak, business stream manager, mining, at SMD. For example, convention mines may use conveyor belts to move unprocessed materials. With undersea mining, these belts are replaced by slurry pumping circuits that use technology similar to that employed in dredging. A high proportion of special metals such as stainless steel are used as well as so-called cathodic protection and electrification process, all with the aim of preventing corrosion. Meanwhile, air pockets in the equipment are housed in pressure vessels designed to withstand the maximum working depth.



The collecting machine ROV will pump material in slurry form to the ship.

Opportunities for Mining and Robotics Companies

The Solwara 1 mining system will cost about $100 million and is expected to last for at least 10 years. That's a significant investment, admits Kapusniak, but it's similar to specialist equipment costs involved with land-based mining and is "in fact cheaper than sinking a shaft or purchasing winding equipment for an underground mine."

Return on investment is governed by many factors, says Kapusniak. But in the case of Nautilus, the potential returns are heightened by the high copper and gold content of undersea ores, the fact that the mining machinery can be moved between sites and redeployed, and the absence of vast quantities of overburden (top-lying material) that requires removal in the case of land-based mines.

The Solwara 1 mining system will cost about $100 million and is expected to last for at least 10 years.

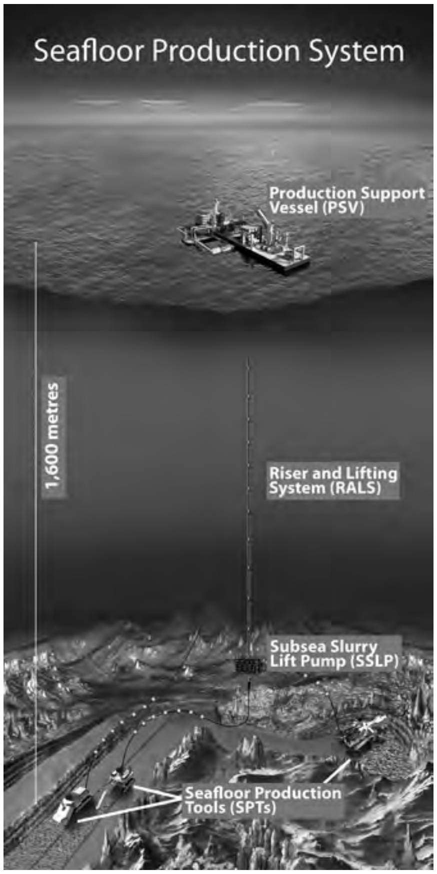
SMD expects the seafloor-mining market to grow rapidly, mirroring the move from land-based oil and gas to offshore oil and gas. "Seafloor massive sulphides, polymetallic nodules, rare earth metals and yttrium, mineral sands, cobalt or titanium-rich caprocks, and other minerals are abundant and as-yet untapped. This pioneering project with Nautilus will unlock access to subsea mineral reserves across the world," Kapusniak told *Robotics Trends*.

These factors will likely lead to increased exploration and a rush to secure subsea-mining claims. While exploration rights in territorial waters are issued by national governments, licenses to explore areas of the seabed in international waters (i.e., those beyond the limits of national jurisdiction) are granted by the International Seabed Authority (ISA), an autonomous Kingston, Jamaica-based international organization established under the 1982 United Nations Convention on the Law of the Sea.

"Major mining and dredging equipment suppliers [some of which are supplying SMD for the Nautilus project], are keen to be involved and do not want to miss out on the coming 'goldrush.' Similarly, we would expect share uptake and/or direct involvement from the remaining big mining houses over time," says Kapusniak.

SMD expects the seafloor-mining market to grow rapidly, mirroring the move from land-based oil and gas to offshore oil and gas.

Investors are certainly getting behind the project. In September, Nautilus secured C$70.5 million in private placement funding, when it issued 27,987,853 shares at C$2.52 per share. A second tranche of approximately 11 million shares closed in October, netting the company another C$27.6 million. Nautilus' major shareholders include Moscow-based Metalloinvest, the largest commercial iron ore producer in Europe with a 21 percent holding, and London-based global mining group Anglo American with an 11.1 percent interest. Nautilius trades on the Toronto and London stock exchanges.



Graphic rendering of the ocean-mining system designed by Nautilus in collaboration with SMD.

Prospecting Beneath the Waves

Mixed messages about the relative abundance of ocean mineral resources give some indication of the uncertainty surrounding the potential of ocean-mining initiatives, however. Nobody knows the exact scale or value of the world's oceanic mineral deposits because only a very small percentage of the deep ocean has been prospected in any detail, says David Cronan, professor of marine geochemistry at Imperial College London.

"The Nautilus deposits are at a depth of about 1,600 meters, and most of the similar deposits are probably around that depth or down to maybe 2,500 meters. Mid-ocean ridge deposits are rather deeper, and that's one of the reasons why they haven't been looked at in the same detail from the mining point of view," says Cronan.

Meanwhile, a Canadian-led study, published in *Geology* in late November, concluded that accessible supplies of deep-sea resources—including copper, gold, and other metals—are not as plentiful as previously believed. Mark Hannington, Goldcorp chair in economic geology at the University of Ottawa and lead author of the study, told *Postmedia News* that what "the world needs to understand is that the oceans—at least on the neo-volcanic zones where people are presently exploring—are not going to make a major impact on the total availability of metals, according to a report in the *Vancouver Sun*.

The study concludes that the aggregate quantities of copper and zinc in the world's oceanic volcanic zones are only slightly more than the total annual amounts of these metals extracted from the world's land-based mines. Hannington's position on ocean mining is "halfway between those who are rushing and those who are not," according to the report.

There seems to be no shortage of resources at the Solwara site, however, with an independent resource analysis in late November causing Nautilus to upgrade its resource estimates by 18 percent to 1.03 million tonnes. The analysis, which followed a 1,475-meter, 99-hole diamond drilling campaign in the Bismarck Sea from November 2010 to May 2011, also saw inferred resources increase 36 percent to 1.8 million tonnes.

With metals such as gold, silver, and copper holding at historically high prices, the company could be sitting—or floating—on billions in potential profits. Over the coming months Nautilus will use multibeam sonar and seismic exploration tools to identify precise targets for drilling.

A Growing List of Players

Meanwhile, another company, Cape Town-based HC Marine and Mineral Projects (IHC MMP), which specializes in building and supplying extraction solutions to the oil, gas, and offshore diamond-mining sectors, is looking to build on its marine-engineering experience to get involved in designing and building ocean-mining ROVs. In 2007, IHC MMP finished construction of a system for De Beers Marine, complete with a 260-tonne deep-sea mining crawler, designed to mine diamonds at depths of up to 150 meters off the African coast. The company is currently designing ROV systems for mining ocean minerals at depths of up to 2,000 meters.

Mixed messages about the relative abundance of ocean mineral resources give some indication of the uncertainty surrounding the potential of ocean-mining initiatives.

Besides the obvious engineering challenges, companies designing ROVs for ocean mining are faced with a shortage of information, says Hans Smit, managing director, IHC MMP. "When you have a land-based mine, there's a very good geological process that everybody follows, so everybody has good data. You know whether you can support structures on it, and you know the nature of what it is that you have to mine and extract," says Smit.

That's not the case with ocean mining, however, as all the world's ocean mineral mining sites are still prospects rather than fully operational facilities. "The first thing we ask a client is, 'What are the material properties that we need to mine?' They often won't have that information for several months until they finish sampling," says Smit.

Until that information is provided, much of the design remains at the concept or prefeasibility stages. Important design work can still be completed, however. "We help the client evaluate his resource, and look at what mining solution he needs, giving him both the capital and the operational costs so that he can go away and look at his financial models, and hopefully make the numbers work so that we can build him a system," says Smit. The final cost for such a system will depend on the size of the machine required, the mineral being mined, and the depth at which the ROV is expected to work, says Smit, and could range from "a couple of million dollars to a couple of hundred million dollars, depending on what is finally required."

Besides the obvious engineering challenges, companies designing ROVs for ocean mining are faced with a shortage of information. … as all the world's ocean mineral mining sites are still prospects rather than fully operational facilities.

With several nations racing to mine the seafloor, customers for ocean-mining ROVs are likely to follow shortly. And some major players are getting involved in ocean mineral exploration under the ISA's auspices. In July, the Ministry of Natural Resources and the Environment of the Russian Federation was granted a license to explore for polymetallic sulphides in the Clarion-Clipperton Fractured Zone, international waters in the Northeastern Equatorial Pacific.

Also in July, China's State Oceanic Administration announced that its Jiaolong remotely operated submersible (with a crew of three) had reached depths in excess of 5,000 meters in international waters between Hawaii and North America. With this capability, Jiaolong could prospect for minerals across more than 70 percent of the world's seabeds. A 7,000-meter test dive is scheduled for 2012.

In mid-November, China's Ocean Mineral Resources Research and Development Association signed a 15-year exploration contract with the ISA for the right to prospect for polymetallic sulfides in a 10,000-square-kilometer area of the southwest Indian Ocean, known as the Southwest Indian Ridge.

Many eyes will be on Nautilus' Solwara 1 site between now and 2013. If the Nautilus operation is successful, then one can expect mining to begin at other marine locations.

Many eyes will be on Nautilus' Solwara 1 site between now and 2013. If the Nautilus operation is successful, then one can expect mining to begin at other marine locations, says Imperial College London's Cronan. "The Nautilus operation is very experimental, in the sense that if it works, it could be the precursor of many similar operations in the Southwestern Pacific and probably in other areas later. But if it doesn't work, then it's back to the drawing board for a few years, I would imagine," says Cronan. "A lot is hanging on it. Not just the value to the company itself, but also whether or not deep-sea mining for this sort of mineral is going to go ahead in the near future." RT

IN BRIEF

Thought leaders, deals, new technologies, and other news

Robot Icons

***Forbidden Planet*'s Robby and other metalloid stars of toy store shelves and films remain as memorable as human characters, and they might even provide lessons for today's robot designers.**

By Linda Rosencrance

For vintage robot collector Marco van Gimst, the most iconic robot is the one you're searching for at any given time.

Robot Lilliput, a 6-inch tall, wind-up yellow robot, made in Japan in the late 1930s/early 1940s, is credited as being the first mass-produced toy robot. But it's another robot—actually a life-size robot—that's probably the most beloved and the most famous robot of all time—Robby the Robot from the 1956 movie *Forbidden Planet.* (Editor's note: A remake of the film is rumored to be in the works, with *Avatar's* James Cameron involved.)

Robby certainly is the top dog of robots in the eyes of Fred Barton, aka The Robotman. Barton's Hollywood-based company, Fred Barton Productions Inc., creates museum-quality replicas of famous robots from movies and television for private collectors and museums. In fact, Barton's company is the exclusive manufacturer and licensee of Robby and other famous movie robots.

"Robby the Robot is possibly the most copied robot ever," he says. "There are probably 100 or 200 toy variations of the big guy—many battery operated and mostly Japanese. These days, just the right toy robot that sold for $3.95 40 years ago can sell for tens of thousands of dollars."

But what makes people want to shell out that kind of money on a robot—life-size robots like the ones Barton makes or even vintage tin toy robots? The answer is the robot's design and popularity, says Barton, who was commissioned to restore the original Robby in the mid-1970s.

"More than R2D2, more than C3PO, more than I, Robot, more than T2 [Terminator 2]—you

DARPAWATCH

What are the defense agency's priorities, and how might they affect the robotics industry? We analyze a recent project to find out.

PROJECT: ADAPTABLE SENSOR SYSTEM (ADAPT)

What it is:	A program aimed at speeding the development of complex sensor systems by harnessing the skills of commercial mobile app developers.
What it will do:	Create hardware and software applications by mimicking methods used in the smartphone industry. Successful applications embedded in unmanned aerial vehicles (UAVs) and other robots used by the military would function as sensors able to readily communicate the information they acquire.
Why DARPA wants it:	Sensors have grown increasingly complex, and development times may not keep pace with the need for their use in rapidly changing military conflicts. The call for ideas represents one more effort by the defense agency to crowdsource innovative solutions.
Possible robotics industry spin-offs:	Sensors developed to facilitate swarm UAV reconnaissance could be applied to industrial, warehouse, or hospital environments, where large numbers of robotic devices perform tasks and gather information simultaneously.
Program contractors:	Open to qualified commercial smartphone app developers.
Project website:	www.darpa.mil/Our_Work/STO/Programs/Adaptable_Navigation_Systems_(ANS).aspx and www.darpa.mil/NewsEvents/Releases/2011/12/05.aspx
Contact person:	Mark Rich, Program Manager, mark.rich@darpa.mil

"Warning, Warning!" With its arms waving in the air and its resonant metallic voice, who could forget the *Lost in Space* robot? Designated as a "Class M-3 Model B9, General Utility Non-Theorizing Environmental Control Robot," Robot (that was his official name in the show) was ever courageous, loyal, morally steadfast, and the unfortunate recipient of constant alliterative insults from another of the show's characters, Dr. Smith. You can still buy a full-size replica of Robot at *LostinSpaceRobot.com* for $24,500. (Photo courtesy B9Creations.)

think robot, you think Robby the Robot," he says. "Even the young generation. It's because Robby has that look. I mean, you see Robby in person, and that's it. It's kind of a '50s retro, but it's still kind of classic and timeless. And you really buy that he's a robot. You wouldn't think there was a man inside it if you look at him. His personality, how he walked and everything—that makes a robot icon; really it's popularity and design."

As far as Barton is concerned, Robby inspired all of the robots of the 1950s. Before Robby, there was no such thing as studio-licensed collectibles or merchandising in the 1950s. "As soon as Robby came out, all these toy manufacturers started making the little tin robots," Barton says.

But for vintage robot collector Marco van Gimst, the most iconic robot is the one you're searching for at any given time. "I think some robots are hyped but not on purpose," he says, referring to one group of robots in particular—the Gang of Five, a set of 15-inch, skirted, battery-operated robots manufactured by the Masudaya Co. in the late 1950s and early 1960s. These robots—Sonic Robot, Target Robot, Machine Man, Lavender Robot, and Radicon Robot—are highly sought after by collectors and individually can sell for tens of thousands of dollars at auction.

Van Gimst thinks Machine Man has become an icon in the robot world only because very few were ever made. But Radicon is his favorite: "Radicon Robot is the first remote-controlled robot. It uses a very simple, very old technique. You can almost see it working. That is what makes the robot so special."

DEALFLOW

Intuitive Surgical

www.intuitivesurgical.com

Intuitive Surgical Inc., Sunnvale, Calif., has reported fourth quarter, 2011 revenue of $497 million, up 28 percent compared with $389 million for the fourth quarter of 2010.

Bluefin Robotics

www.bluefinrobotics.com

Bluefin Robotics Corp., Quincy, Mass., has received ISO 9001:2008 Certification for the design, development, manufacturing, operation, and servicing of its autonomous underwater vehicles (AUVs) and related products. The certification was granted by the International Organization for Standardization, TÜV SÜD America Inc., a nongovernmental organization that is the world's largest developer and publisher of international standards.

re2

www.resquared.com

Pittsburgh-based re2 Inc. has been selected to develop a two-arm Highly Dexterous Manipulation System (HDMS) for the U.S. Army's Armament Research, Development, and Engineering Center (ARDEC) under a Phase II Army Small Business Innovation Research (SBIR) competitive contract. The U.S. Army chose the company to create a dual-arm manipulation system to improve robotic ordnance disposal capabilities.

Intellibot Robotics

http://intellibotrobotics.com

Intellibot Robotics Inc., a manufacturer of robotic commercial floor cleaners and recipient of a *Robotics Trends* 2011 Robie award, has moved its headquarters to Portland, Ore. Previously based in Richmond, Va., Intellibot will maintain its manufacturing and engineering operations in that state.

George Washington University Hospital

www.gwhospital.com

The George Washington University Hospital, Washington, D.C., a regional leader in the field of robotic surgery and home to one of the largest robotic programs in the nation, will also be home to the region's first multispecialty robotic training center in late summer 2012.

(continued on next page)

DEALFLOW

(continued from previous page)

FMC Technologies and Schilling Robotics

www.fmctechnologies.com and *www.schilling.com*

Houston-based FMC Technologies, a provider of technology solutions for the energy industry, has given notice to exercise its purchase option for the remaining 55 percent of outstanding shares of Schilling Robotics LLC, Davis, Calif., a developer of underwater robotic systems. The transaction is expected to close on or about March 30, 2012. FMC purchased its existing 45 percent interest in Schilling and obtained the purchase option in 2008.

Mazor Robotics

www.mazorrobotics.com

Mazor Robotics Ltd., an Israel-based developer of surgical robots and complementary products, has announced that the European Patent Office granted the company European Patent No. 1414362 entitled "Miniature Bone-mounted Surgical Robot," which covers Mazor's flagship product, Renaissance.

RMT Robotics

www.rmtrobotics.com

Grimsby, Ontario-based RMT Robotics Ltd., a Cimcorp Oy company and the manufacturer and integrator of ADAM intelligent mobile robots, has announced the sale of a small fleet of ADAMs to a large international manufacturer of industrial products. The equipment will be installed in the customer's manufacturing facility in Ohio, and the initial system will be operational in the first quarter of 2012.

Maplesoft

www.maplesoft.com

Waterloo, Ontario-based Maplesoft, a subsidiary of Cybernet Systems Co. Ltd. in Japan, has announced a major adoption of its products by NASA's Jet Propulsion Laboratory (JPL). JPL is implementing Maple, MapleSim, and MapleNet in its various projects.

QinetiQ North America

www.qinetiq-na.com

QinetiQ North America Inc., McLean, Va., has announced that its Dragon Runner 10 (DR10) has been selected by the Joint Improvised Explosive Device Defeat Organization (JIEDDO) in response to a Joint Urgent Operations Needs Statement (JUONS) for lightweight, throwable robots. This order for more than 100 DR10 robots represents the first significant U.S. military procurement of this new class of robot.

IN BRIEF

Exploring the Oceans for the Price of a Luxury Car

Designed to provide scientists with greater levels of data in a more economic model, the latest version of iRobot's Seaglider could find a ready market among governments and companies seeking to better understand the earth's oceans, while searching for sustainable ways to recover its resources.

By Esther Shein

Editor's Note: See related stories pages 1 and 9.

iRobot Corp. officials classify the newest version of their popular Seaglider unmanned submersible as a long-endurance vehicle that's been newly reconfigured to significantly increase its volume and mass payload capabilities.

This is something of an understatement: The previous Seaglider model had a payload volume of 3,200 cubic centimeters. But with the newer version, engineers at the Bedford, Mass.-based company were able to expand the volume a significant 6.5 times to 21,000 cubic centimeters, explains David Heinz, vice president of iRobot's maritime division. That wealth of additional space will allow the craft to carry more sensors and other gear.

In shallow water, the Seaglider is "very efficient in terms of battery usage, and provides the capability to go deep and do that mission without having to change out equipment or reballast," Heinz says. This gives scientists more flexibility to decide the types of data they want to capture.

Indeed, the Seaglider uses an ingenious, ultra-efficient propulsion system. Changes in buoyancy allow the craft to glide up and down through the watery depths, drastically reducing power requirements, and extending the craft's operational length. Moreover, it can operate without the need for a support ship. Upon surfacing, the Seaglider uses its antenna to communicate to a base station, which can be located anywhere in the world, and send data and receive commands.

Saving Thousands of Dollars a Day

"A research ship typically costs $40,000 a day to operate, and a glider costs $400 a day," Heinz notes. "So imagine for ocean studies our ability to gather much larger volumes of data at a larger order of magnitude at a lower cost." For example, to study temperature fluctuations that can affect climate changes, putting several gliders in the ocean provides the ability to collect more samples. "With a glider I can sample every 20 meters, and because the resolution is better, it provides a much better fidelity model," Heinz says.

The Seaglider can travel thousands of miles and is designed for missions lasting several months. The new sensors can measure such things as temperature, salinity, depths, pressure, and currents.

Heinz puts the Seaglider's costs at around $125,000. However, depending on the number of sensors, the price can double. Surprisingly, given the craft's relatively low cost, only about 135 gliders have been deployed in the past six years. A number of niche markets do exist, however, which could greatly increase sales.

Environmental compliance is one. When a drilling operation starts, studies can be conducted "to determine whether there are toxins going in the water and are they impacting fish life, and is there too much noise driving away mammals in that area,'' Heinz explains.

Another potential use is to monitor ongoing offshore drilling operations or to search out promising new drilling locations. Currently, ships are deployed to monitor what is going on around that platform, Heinz says, to determine whether there is gas, oil, or hydro gas, or other minerals in high concentrations that are worthy of exploring, "We think we can put sensors on gliders that provide that [information] at a fraction of the cost."

Seagliders awaiting deployment. (Photo courtesy iRobot.)

Fishing for Robotic Propulsion Secrets

From manta rays to tuna, the Navy thinks sea creatures could inspire advanced autonomous underwater vehicle designs.

By Linda Rosencrance

RoboTuna. While its name might elicit a few giggles, its purpose is no laughing matter.

A robotic fish that mimics the motion of a bluefin tuna, RoboTuna was developed by MIT in the mid-1990s. The thinking was that because the tuna is one of the fastest fish in the ocean, a robotic tuna that could mimic the movements of a real tuna would be a perfect underwater vehicle.

After several iterations, RoboTuna resurfaced as GhostSwimmer, created by researchers at Boston Engineering Corp. and the Franklin W. Olin College of Engineering for the U.S. Navy. GhostSwimmer was developed after an extensive study of the hydrodynamics of the tuna's body motion; it mimics the actual motion of a tuna. The Navy wants to use the technology to someday develop an extremely efficient submarine.

The U.S. Navy wants to use technology based on a tuna's hydrodynamics to someday develop an extremely efficient submarine.

"The military, particularly the Navy, has been interested in robotic fish for a number of years," says John Long, professor and chair of biology at Vassar College, Poughkeepsie, N.Y., as well as the director of the institution's Interdisciplinary Robotics Research Laboratory. "Tunas can cover a lot of ground very efficiently. And so it's one way to have either a remotely operated vehicle or a vehicle that goes out and measures the presence of other vessels. Or it goes out and tracks—in a commercial application—a fast-moving oil spill, for example."

Long says the Navy is interested in fish not just because of the way they move, but because of the way they sense the underwater world. "Underwater presents a lot of challenges, because you can't do GPS, for example, underwater," Long says. "So you have to communicate usually acoustically, making pings and picking those pings up with sonar, things like that. You can use sonar in a kind of radar-like way underwater."

The Navy is interested in fish not just because of the way they move, but because of the way they sense the underwater world.

For instance, take sharks. They have a really keen chemical sense, very good vision, and an electrical sense, Long says. "So a shark can detect a flounder that's buried itself under the sand that you can't see nor can you smell," he says. "A shark, if it's close enough, can detect the electrical signature that the fish makes. And biologists have identified these organs that do this electroreception."

He continues, "So think about making an electroreceptive organ for your robot so you can detect if maybe somebody has buried some cables. And thinking about counter measures in naval operations—maybe you're nearshore operations and you're looking for a buried power plant or something like that. So the sensory capabilities of fish and sharks underwater [are] of interest."

Yet another researcher, Frank Fish, professor of biology at West Chester University, along with engineers from the University of Virginia, Princeton, and UCLA, has been asked to study manta rays by the U.S. Office of Naval Research with potential applications to developing flapping foils—flapping wing-like structures—as potential replacements for propellers.

Fish and his colleagues are trying to understand the hydrodynamics and material properties of the rays. The idea is to eventually develop a stealthy biorobot, he says. "The applications are not something we are necessarily privy to, but basically the Navy is looking for alternatives rather than conventional screw propellers," Fish says.

"A lot of the research that's been done on fish and robots [has] really been confined to small fish. Although there are some exceptions, like the famous RoboTuna," he says. "So people worry about the ability to scale up those sorts of propulsive systems, and build robots based upon fish."

Researchers are trying to understand the hydrodynamics and material properties of the rays.

Fish and his team are hoping to figure out how the manta rays move with high speed and high efficiency. They've traveled the world, including a stop at Yap, an island in Micronesia—manta rays swim to the protected waters inside the Yap's reefs so the tiny fish living there can clean them—to videotape the rays to generate 3-D images of their swimming capabilities.

But for up-close-and-personal research he studies the smaller stingray in his lab at West Chester. He uses computed tomography scans to study their shapes so the researchers can mimic their look and efficiency. The team's findings will be handed over to engineers to design and build a submarine manta robot.

"We're not necessarily building a robotic manta ray," he notes, adding, "We're not copying it exactly." Instead, he says, "We're trying to distill out the best things from the manta, and any other ray organism, and put them into our biorobot. We've been at it for over three years. We have two more years on it." RT

Building Buildings with Robots

Skilled labor shortages, the need for intelligent, energy-efficient structures, and cost pressures could create a major niche for robots tasked with on-site assembly of everything from homes to skyscrapers—with Asia leading the way.

By Linda Rosencrance

While robots have proven indispensable in sectors as varied as aerospace, automotive manufacturing, complex medical procedures, and myriad other areas, to date their use has made few inroads into the construction industry. To be sure, industrial robots are commonly employed in areas related to the construction industry, such as welding I-beams for buildings, painting walls, as well as palletizing and packaging building products. Some robots also build prefabricated walls that are assembled on the job site. But the final assembly on the site itself takes place by hand or through the use of manually controlled cranes.

According to thought leaders, the construction industry remains stuck in the preindustrial age.

That's prompted thought leaders such as Matthias Kohler, an architect and professor at the ETH (Eidgenossische Technische Hochschule) in Zurich, to conclude that the construction industry—to put it bluntly—remains stuck in the preindustrial age. "The actual putting together of a building on-site has remained hand labor," Kohler says. "But we think within the next decades there will be some shifts to that situation."

Today, buildings are constructed by people who perform the necessary tasks using equipment, according to the paper "Robotizing Workforce in Future Built Environments," written by Ger Maas and Frans van Gassel, assistant professors in the Department of Architecture, Building and Planning, Eindhoven University of Technology, The Netherlands. But the pair see a better way. They write: "Mechanizing, robotizing and automating construction processes is necessary in order to reduce production times and costs, improve working conditions, avoid dangerous [conditions], allow work to be performed that people cannot do and increase performance." According to the authors, the challenge entails "designing new products with appropriate working methods, which can be easy to robotize the workforce."

Kohler and his colleague, Fabio Gramazio, also an ETH architect, agree that there are advantages to using robots in construction, including precision and consistency, which are often subject to human error. The researchers, who operate the Gramazio & Kohler architectural and design studio, contend that if you combine automated robots with digital design programs in common use today, those robots can maneuver materials into shapes and patterns that specifically require exact repetition and replication.

There are advantages to using robots in construction, including precision and consistency, which are often subject to human error.

The architects' goal is not to automate the complete building process, but to identify the tasks for which a robotic process makes sense, then integrate those processes into the design phase, so robots and human construction workers can work together to assemble new buildings.

"It all comes down to building functional surfaces as economically as possible," Kohler says. "If you take a robot ... [it] can repeat a task endlessly. Robots have evolved over the last one or two decades. Before, they would just do the same task over and over. But now robots are hooked up to the CAD [computer-aided design] programs on the computers and you can tell the robot to do a different, individual task each time it moves."

Kohler's team is investigating a concept known as "digital materiality," the intercon-

Fabio Gramazio and Matthias Kohler, who operate Gramazio & Kohler architectural and design studio, recently joined with Raffaello D'Andrea, a professor at the Institute for Dynamic Systems and Control in Zurich, to demonstrate a radical approach to building complex structures using autonomous quadrocopters, which they call Flight Assembled Architecture. With the requisite algorithms tested, the team's next step is to study how well their method can be scaled up to create actual buildings. (Photo courtesy Gramazio & Kohler.)

nection of data and material and the implications that interconnection has on architectural design. They're also exploring the capability of robots to make design changes while construction is under way, currently a cumbersome and expensive task, and one that contractors typically loathe.

Kohler says such research is important for another reason as well. Architecture, as practiced today, is very much customized to each individual building. "Each building you build is different, so it's critical that the [robots] you use to build something with can also adapt to these variations and differentiations in architecture," he says.

Learning Curves

That's a lofty goal to be sure. But even in the short term, industry experts believe robotics can significantly change how buildings are made. "I think robots can be used for loading and they can be used to place prefab components and nail them, or join them together with some sort of fastener," says Dean Elkins, senior general manager at Dayton, Ohio-based Motoman Robotics Corp., a division of Yaskawa America Inc. "I think it's in the future when you're going to see robots providing the entire construction."

That's because robots are restricted to a certain work envelope—meaning a robot can only cost-effectively reach so far when handling or assembling materials, Elkins says. Second, humans possess skills robots can't match, in particular vision and touch.

"We can use machine vision to find parts and orient accordingly, and we can make the robot move to a certain position. [But on their own] robots are not quite there yet," Elkins says. "In terms of touch, robots are great at placing something somewhere, maybe putting a fastener somewhere. If there's force feedback, for example, a craftsman may be able to sense a smoothness of a surface by touching it. Robots don't really have that touch yet, so they're a little bit more limited in that regard. I don't know if they'll ever take the place of craftsmen."

Earl Raynal, sales manager at Motion Controls Robotics Inc. (MCRI), Fremont, Ohio, is another proponent of using robots in construction. MCRI provides robotic automation solutions for a variety of industries including construction, and as a systems integrator, the company also designs, integrates, and installs Fanuc robotic systems throughout North America.

"There's enough repetition in building a skyscraper that I can envision a piece of automation that would bring pieces of steel to their locations where they need to be fixed, and drive in bolts or rivets," he says. "So construction cranes that work on skyscrapers—that motion is very repetitive and very predictable. If you take out wind and other variables, then potentially that sort of application could be automated. At that point I would call that a fully automatic robot."

Raynal says although construction cranes are normally manned, and probably always will be to some extent, automation could certainly be added to make them more robotic-like—the loading and unloading points on the construction site could be taught to the crane so that macro movements would be automated to make them most efficient, while the precise, final positioning could be done by an operator.

"The crane operator could be taken out of the crane, and the crane could be controlled by workers who are doing the assembly work," he says. "Remote controls are available to do this already, and may, in fact, be in use."

Robots could also be used for building trusses for homes and commercial buildings that use truss-built roofs, Raynal says. "It's a very repetitive process, but today that process is very manual and very labor intensive. But it's also prone to error, because you're doing the same thing over and over. If you could apply robots to do that work in a cost-effective, efficient manner, you would have better construction, and a more precise, stronger structure."

Bridge repair is also a terrific application for robotic work, according to Raynal. "America has an aging highway infrastructure and a big part of that is aging bridges that need to be inspected and repaired, sand blasted, and painted," he says. "The inspection, sand blasting, and painting could all be done with robots mounted on girders/hangars. Vision [a vision system added to the robotic application] would be used to look for specific faults. Sand blasting and painting are processes that don't require a lot of precision, which reduces the cost and allows for more a flexible robotic cell (the complete robotic system) setup. This dirty, labor-intensive, and highly disruptive work could be done with higher speed, less invasive robotics, and in the dead of the night with minimal labor."

Although construction cranes are normally manned, and probably always will be to some extent, automation could certainly be added to them to make them more robotic-like.

But could robotics be used to build houses? Raynal says he'd start with the modular home business, because it's a smaller-footprint production where repetitive designs are used. "Robots along with hard automation could absolutely be employed to build [the framing] for these structures," he says. "Robotics could also be used for the highly repetitive tasks of painting and shingling. Resulting assemblies would have more precision and repeatability than current structures. And, design enhancements and revisions would be controlled through software, introducing better control of the change process."

While significant portions of assembling modular homes could be done with robots, the key is to attain sufficient volume to justify the expense of setting up the robotic automation, Raynal says.

Bridge repair is also a terrific application for robotic work.

The High Rise of Asia

Rapidly growing Asian economies could provide the required volumes for the robotic construction of homes and other structures. Kohler and Gramazio are currently investigating the use of robotic fabrication in the design and construction of high-rise buildings in Singapore. Because Singapore is a dense, urban metropolis with a growing population, the team believes it could be the catalyst to increased use of robotics processes in construction everywhere.

Additionally, Singapore would benefit from adopting robotic processes in construction because it lacks skilled construction workers as well as available land for building, Kohler says. Both factors can add greatly to construction costs. For those reasons, Singapore's government is on board with the idea of automating building processes.

Rapidly growing Asian economies could provide the required volumes for the robotic construction of homes and other structures.

Other areas of the world might quickly follow Singapore's example, if demographic projections are to be believed. The world building materials market is predicted to reach $706.7 billion by 2015, according to a report by Global Industry Analysts Inc., with the Asia-Pacific region leading that growth.

According to the report, this growth is mainly driven by strong construction activities as a result of mass exodus of manufacturing and production bases to low-cost Asian countries, continuous industrialization in regional powerhouses such as China and India, increasing income levels, higher spending power, as well as improving standards of living, resulting in higher demand for residential and commercial construction.

Other important factors expected to drive this growth include a resurgence in residential and commercial construction activity, recovery in infrastructure spending by governments, improvement in liquidity in the financial markets, softening of interest rates, and continued industrialization in developing countries, according to the report.

The projected increase in public construction activity will pave the way for the greater consumption of building material.

In addition, the projected increase in public construction activity will pave the way for the greater consumption of building material. Government-sponsored economic stimulus packages for the construction industry will help drive demand for building materials in the short- to medium-term period, according to the report.

Couple that with the fact that in 2011 robot sales increased 18 percent to 140,000 units—a new high—as well as the expectation that robot sales will continue to increase about 6 percent per year on average from 2012 and 2014, reaching about 167,000 units in 2014, according to the International Federation of Robotics (IFR). This is good news for systems integrators as well as robot manufacturers.

Robot sales are expected to increase particularly in North America and in other countries in Southeast Asia. And investments in Japan will gain momentum as reconstruction and new projects are carried out in the coming months as a result of the massive earthquake in Japan in 2011, according to the IFR.

But it's the robot supply to China that is expected to increase substantially in the next several years, which has caught the attention of robotics manufacturers and which bodes well for their use in the building sector of that nation. Indeed, by 2014, China is expected to be on top of the robot market.

The robot supply to China is expected to increase substantially in the next several years, which bodes well for the use of robotics in the building sector of that nation.

"We've done studies recently looking at the power consumption of robots based on average kilowatt-hours to run the robot. It costs 15 cents an hour to run that machine, compared to a Chinese laborer who costs about $3 an hour and compared to a more skilled laborer in the Americas who gets $15 to $25 an hour," Elkins says. "We've proven that there's a strong business case for using robots from an economic justification standpoint. Robots are what are going to help us keep competitive ... particularly in countries like Russia, India, and China."

Looking further into the future, MCRI's Raynal says a huge spike in construction may be on the horizon. "In 20, 30, or 40 years out, futurists say we'll be hitting a peak in population growth, and at the same time we have aging buildings—post World War II construction—that don't really fit today's lifestyle," he says. "So companies can get on the robotics bandwagon to build better buildings and save money at the same time." RT

The Coming Boom in Robotic Parking Garages

Imagine your vehicle delivered to you in moments by an automated valet summoned via your smartphone.

By Esther Shein

The old adage in real estate is location, location, location. When it comes to parking lots, it is space, space, space. And space is precisely the idea behind a small but growing number of parking garages that use robotics to move and park more than two times as many cars as conventional garages.

That space saving can mean huge revenues in cities like New York, where individual spaces in conventional parking garages can sell for six figures. Automated garages offer reduced operational expenses as well, since they don't require attendants. But perhaps their biggest attraction to potential customers is a vastly improved user experience. Forget hard-to-navigate ramps, rush-hour congestion, exhaust-laden air, or the scary enclosed spaces car owners must walk through when searching for their vehicles.

A small but growing number of parking garages use robotics to move and park more than two times as many cars as conventional garages.

Robotic garages, by contrast, provide a genteel, *Jetsons'*-like experience. In November, the *Miami Herald* reported that Germany-based Porsche Design Group and a local developer are planning a $560 million condo in Sunny Isle Beach, Fla., with glass elevators that will take drivers to their units—while they sit in their cars, the first such design in the world. A robotic arm that works like an automatic plank will take the car and put it in the elevator along with the driver, bring them up to the driver's floor, leave the driver in front of his or her condo unit, and then park the car, according to the *Herald*. Residents will be able to see their cars from their living rooms.

Ramping Up

Little wonder that the idea is taking hold, especially among real estate developers, and it represents what could become a significant niche within the robotics industry. State-of-the-art robotic garages require everything from software to user interfaces to the customized mechanical systems that include elevators and other devices that fetch vehicles and deliver them directly to waiting customers.

Jeff Hyde, vice president of design and development for West Hempstead, N.Y.-based Automotion Parking Systems LLC, which has three automated parking systems in New York, says that while working on a project in downtown Manhattan in 2005, company officials were trying to figure out how to create as much value as they could from a residential and commercial development project. One way was to keep a parking garage on-site, he says, and they began exploring their options. The company chairman went to Germany to visit Stolzer Parkhaus, a firm specializing in automatic car-parking systems. He brought the concept back to the states and applied it to the Manhattan development project, which enabled Automotion to create a parking garage with 70 spaces, as opposed to 24 if the developer had put in a conventional garage, Hyde says. "We get roughly three times as many cars using automated parking versus conventional," he says.

State-of-the-art robotic garages represent what could become a significant niche within the robotics industry.

Another company, Robotic Parking Systems Inc., based in Clearwater, Fla., also maintains that automated parking garages allow two times or more cars in the same footprint of space than a conventional parking garage. "The reason for that is you don't have to have

Automotion, one of several companies involved in the design and construction of robotic parking garages, describes its operation as a “vending machine for vehicles.” The technology can transport people sitting in the comfort of their vehicles directly to the doors of their residences, then whisk the car away for storage, retrieving it again on demand. Robotic garages can also be used as public parking facilities. (Photos courtesy Automotion Parking Systems LLC.)

ramps for driving around to different levels or aisles to drive down,” explains Chief Administrative Officer Mary Lou DeWynGaert. “The cars can be in a racking system and are close together, and you don’t have to provide space for a person to get out. You don’t have pedestrian areas for walkways, and by eliminating that and using a steel rack system you get more cars in.” Robotic Parking has four automated garages: one in New Jersey, two in Dubai, and one that is under construction in Abu Dhabi.

The cost to build these types of garages varies, depending on the number of spaces they have, DeWynGaert says. Since they are custom designed, the price has to be calculated for each project, she says. Hyde puts the cost at between $20,000 and $25,000 per space, based on roughly 100 spaces. By contrast, conventional parking garages run between $18,000 and $40,000 a space for a standard 100-space garage, he says.

A Vending Machine for Vehicles

Automotion’s garages use a space of 125x75x14 feet deep with a two-level pallet and racking system. A car pulls into an entry room that resembles a one-car garage in a residential home, Hyde says. It is about 10x20 feet with the pallet in the middle. “The only thing that ever gets moved is the pallet in the automated system,” he explains. “It’s a vending machine for vehicles.” The pallet moves horizontally and vertically from that room into an “automated parking vault.” In the meantime, the driver walks over to a cash management kiosk and through a series of questions is identified and given a parking ticket with a time stamp in order to be charged for the amount of time the car is parked. When the driver returns, he or she only needs to put the ticket back into the kiosk and pay, and then the machine identifies the vehicle and returns it to the “entry/exit room.”

The system is designed to be completely automated, with no need for parking attendants, Hyde says, adding that it is up to the building management to determine how to run the garage. The technology is very similar to elevators, he explains, using a series of sensors and motors that identify the distances a car needs to move. “Every millimeter of movement through the parking system is monitored.” Light sensors measure a vehicle’s dimensions, and with the use of laser scanners the car is placed properly on a pallet.

“All we’ve done is take a car and move it vertically and then horizontally to a space through a series of automated movements,” says Hyde. “This gives us the ability to manage time and space.” Parking has become a science, he adds, because the technology makes it possible to determine how long it takes to park and retrieve a vehicle. “So in a place like New York City, where parking is so in demand, it takes a minute and a half to retrieve your car with the automated system.” Once a driver walks up to the kiosk and pays for the parking time, it takes 90 seconds to walk to his or her car and drive away, he says.

“Anyone who has ever parked a car in New York City knows it’s certainly not going to be 90 seconds from the time they walk in to retrieve their car,” Hyde notes. “Being able to manage that time and the amount of space we dedicate to parking gives us as real estate investors the ability to create more valuable real estate development."

Robotic Parking also uses stacker systems horizontally and vertically to move cars, says DeWynGaert. "Our system is different in that each motion is done by different machines, so you can have a number of cars in motion at any one time." Each machine performs a different function: Once a car is picked up, one machine moves it horizontally, while another moves it vertically, and a third one moves it into a rack. In the company's 765-space garage in Dubai, she notes, there can be up to 32 cars in motion at any one time being moved horizontally, vertically, and put into the rack. Because the car is put on a pallet, the machines don't ever touch it and once it is placed in its slot in the rack, none of the oil or dirt from the car above leaks onto it, DeWynGaert says. Nor are there parking fumes to contend with.

Both Automotion and Robotic Parking use stacker systems horizontally and vertically to move cars.

Like Automotion, a driver is required to put a card in a kiosk machine, but the driver is told which exit station the car will be at, and the driver walks there to pick up the car. All entry/exit stations are on the ground level and the lobbies are well lit, she says. "We recommend an operator for each shift."

Robotic Parking has partnered with GE and uses its PLC project logic controllers, as well as with Stratus Technology for redundancy in its servers. "If an error occurs with the computer software that runs this, it automatically switches over to another server," DeWynGaert says, "so transactions are redundant and can run on a different system. There's immediate backup."

Automotion's lead time on projects is between three and five years, and the company is currently working on projects around the country.

Automotion's lead time on projects is between three and five years, says Hyde, and the company is currently working on projects around the country. "We can create parking in a facility where conventional [parking] is not an option," he says. "It gives us the ability to reevaluate the way a real estate development [project] is created … it's faster, more efficient, and it's very green."

And when the real estate market fully recovers, it could become the default way to build or remodel parking facilities the world over. RT

When It Takes a Snake

The slogan for OC Robotics' Explorer snake-arms is "reaching the unreachable." In reality, its longest snake is 4.5 meters and can lift a 20-kilogram payload through a 150-millimeter hole.

By Natasha Lomas

A composite photo of OC Robotics' Explorer snake robot reveals its flexibility, an asset when the device operates in cramped quarters. (Photo Courtesy OC Robotics.)

Bristol, U.K.-based OC Robotics has been designing snake-arm robots since 1997, targeting high-value, confined spaces such as nuclear reactors and aircraft wings, where it's difficult or dangerous for humans or less pliant robots to operate. The business was founded by Managing Director Rob Buckingham and Technical Director Andrew Graham, who began work on their concept of robots snaking pretzel-like into tight spaces in Buckingham's attic. Seed funding in 2001 enabled the company to build its first prototypes. Today, OC Robotics employs 15 people and has generated revenue of around $10.7 million.

Much of OC Robotics' business has been building custom robots. But in 2010, the company launched its Explorer line, a range of general-purpose, modular snake-arms costing hundreds of thousands of dollars each.

The Explorers' snake-arms are wire-rope driven. That is, wires running the length of the snake's hollow casing link to an actuator pack at the base, where the motors are housed. This design reduces the snake-arm's weight and enables it to be longer and thinner—essential for operating in what can be very confined environments. It also allows the electronics to be shielded from any radioactivity or toxins the snake-arm encounters.

Smart, Common Approach

Dennis Hong, associate professor of mechanical engineering at Virginia Tech, Blacksburg, Va., describes it as "a smart, yet common approach" for a snake-robot design. He notes, "It is important to have most of the actuators on the base to reduce the weight distribution and thus cables are often used.

"The challenge of a snake-arm design is it needs many degrees of freedom and, since it is a long arm, how to provide enough torque at the joints to hold its own weight and some more for the task. Software for path planning, etc., is also important and difficult," he adds.

A human operator controls Explorer using an Xbox-style joypad in conjunction with software running on a laptop. The control system is easy enough to be picked up in minutes, according to Buckingham. The operator "flies" the tip of the snake and the software "nose-follows" the rest.

In 2010, OC Robotics launched its Explorer line, a range of general-purpose, modular snake-arms.

"We let the operator control where the snake goes—i.e., 'fly the nose'—and then the computer works out what should happen with the rest of it," he says. "In my view that's not AI, but it is very clever control."

Explorer snake-arms range from 1 meter to 4.5 meters long, with diameters between 40 millimeters and 150 millimeters. Each actuator pack supports multiple lengths but just one diameter. Tools such as lights, cameras, water jetters, cutters, and grippers are mounted at the nose, with services delivered via the snake's hollow innards.

Remote Monitoring Tool

OC Robotics is pitching Explorer to utility companies as a remote monitoring tool for use in nuclear power plants where downtime is expensive. Other energy sector uses include probing pressure vessels and gas turbines. The company is also targeting Explorer at the nuclear decommissioning industry, where it would be used to help identify types of hazardous waste.

This summer OC demoed two Explorer snake-arms, each with 22 degrees of freedom, to Sellafield, a nuclear reprocessing site in Cumbria, U.K. Sellafield hasn't purchased any Explorers yet but has provided OC Robotics with roughly $270,000 to fund trials.

In January, the company announced that it had "delivered a snake-arm robot to the University of Sheffield Advanced Manufacturing Research Centre (AMRC). In a prepared statement OC Robotics noted, "The snake-arm will be used to deliver a variety of end-effectors into confined spaces, and automate processes that are currently dangerous and time-consuming to perform."

In the meantime, Buckingham is confident the wait will pay off. "You've got to invest to get into the nuclear industry but once you're in, you're likely to be there for a long time," he says.

OC Robotics' snake-arms have also had interest from Japan, for the cleanup of the tsunami-damaged Fukushima reactor. "That's a decommissioning project of enormous political significance where effectively money is no object," adds Buckingham.

Commercial snake-arms are rare enough the company hasn't needed to pay for advertising, relying instead on the Internet and industry word-of-mouth. "There are needs out there, and there are people looking," says Buckingham. "A lot of people found out about us a long time ago, and they've just been tracking it. They're not willing to buy something which is brand new and unproven. But as it becomes more mature, they've been thinking about it for a while." RT

OC Robotics is pitching Explorer to utility companies as a remote monitoring tool for use in nuclear power plants where downtime is expensive.

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A New Take on Autonomy

Getting large teams of robots to collaborate is the work of researcher Regis Vincent, who envisions applications that include mapping nuclear contamination.

Interview by Ellen Muraskin, Robotics Trends *Contributor*

Regis Vincent is senior computer scientist at SRI International, a nonprofit research institute conducting client-sponsored research and development in the sciences and technology. The focus of Vincent's research at SRI is the collaboration of large teams of robots.

RT: How do you define "autonomy" in your work with robots?

Vincent: We don't really want a robot to think for itself. We're working on what we call "assisted autonomy," in which I want the robot to do the boring, repetitive tasks it does well, but leave the harder tasks and decisions to me. For example, say we have a robot that can move and grasp an object. All the movement to that object—the avoiding of obstacles, the extension of the arm—are the boring and automatic parts of the task. Once the object is grasped, however, all the manipulation of that object may be remote controlled by humans. Then once that task is performed, I want automation to take over again. I want to tell that robot "go and dock yourself" and have that robot find its way back to its docking station and recharge without my having to worry how it does that.

RT: How do you coordinate the "autonomous" movement of a group of robots?

Vincent: We just implemented a route system where the robots travel in one direction on the right side of the wall, and the other [robots travel] in the other direction on their right. You treat those as highways of travel. Then you need to coordinate points on the map [where those lanes intersect], and those points have a [virtual] traffic light. You coordinate that. That's one easy way of avoiding collision.

RT: Does the robots' human system administrator have a sort of flight traffic controller interface?

Vincent: The operator has a god's-eye view of all the robots' locations and what they're doing. He could ultimately remote control them, but with higher robots that's unlikely to be necessary unless something drastic happens, like if a robot becomes disabled and stops responding. It works more like asset management. The human has a list of tasks he wants done, and he takes a bunch of robot assets and determines, "OK, you guys have to clear that portion of the building." How that happens, where they should go, is not the human's responsibility. It's the computer's responsibility to orchestrate that. The human just assigns his chosen number of robots to each task.

RT: What kind of computer is running this multirobot negotiation program?

Vincent: It's mostly a single laptop. It doesn't need much compute power. The hardest task is getting all the info to that computer reliably. RT

Editor's Note: This interview is an adaptation of a lengthier conversation between Regis Vincent and Ellen Muraskin. Read the entire version online at www.roboticsbusinessreview.com/businessnews/view/a-new-take-on-autonomy/.