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BY AMY DEBRA FELDMAN | GRAPHICS BY XPLANE.COM

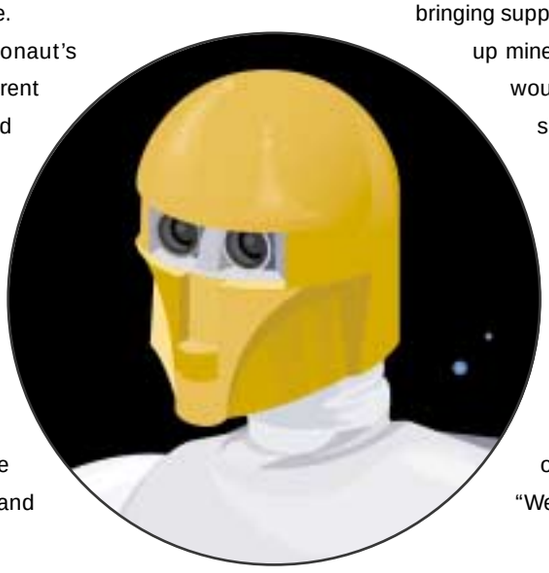
deep space explorer

NASA'S ROBOTIC ASTRONAUT POWERS UP FOR EMERGENCY SITUATIONS

It's one thing to have a robot assisting inside a spacecraft. It's quite another to send one to the outside of a carrier to deal with an emergency as the ship drifts through space. Modern space robots have acted as exploratory testers, landing on celestial bodies such as Mars and asteroids where risk and expense deter astronaut teams. But the typical robot's hand resembles a claw or hook that requires specially created tools, so even with programming, a robot has its limits. Enter Robonaut—NASA's latest helper.

This robotic astronaut has a single leg that plugs into a stabilizing socket on the spacecraft's exterior and hands designed to fit inside human-size gloves. It receives commands from an operator wearing a virtual-reality headset and glove inside the craft. The setup allows the operator to feel as if she were the robot, explains Robert Ambrose, Ph.D., head of the Robonaut project at the Johnson Space Center in Houston. The operator directs Robonaut through verbal instructions or by moving her hand, causing Robonaut to mirror her action. "Our goal is to be able to [have Robonaut] work side by side with astronauts in space," explains Ambrose.

Combined with the wrist, Robonaut's dexterous hands can move in 14 different ways, which enables it to grasp and manipulate objects with more flexibility than most robots, says Myron A. Diftler, chief mechanical engineer on NASA's 15-person Robonaut team. An employee of **Lockheed Martin Corp. (LMT)**, Diftler helped develop Robonaut's hand, wrist, body and brainstem. Its fingers are so flexible, "it could almost play the piano," adds John R. Huff, chairman and CEO of **Oceaneering International Inc. (OII)**, which helped develop the gloves and forearm motor.



Another remarkable feature of Robonaut is its short-term memory. When the operator says, "Pick up the wrench," the robot asks itself, "Where did I last see the wrench?" Using specialty software, Robonaut can search data such as sounds, images and vibrations to locate an item. The software is modeled after the hippocampus, the short-term memory structure in human brains. The brainstem, consisting of materials too large to fit into a human-size head, attaches to the back of the current prototype.

Companies including **Alcoa Inc. (AA)** and **Kaydon Corp. (KDN)** contributed parts; **DuPont (DD)** provided the robot's outer fabric. Existing technologies, such as computers, voice-recognition software, encoders, chips and cameras from **Compaq Computer Corp. (CPQ)**, **IBM Corp. (IBM)**, **Hewlett-Packard Co. (HWP)**, **Motorola Inc. (MOT)** and **Sony Corp. (SNE)**, respectively, give Robonaut its ability to see, think, move, hear and speak.

A similar robot could have many uses here on Earth, such as bringing supplies to troops on a battlefield or digging up mines, Ambrose says. It could also carry a wounded soldier to safety, performing simple medical tasks in the process, such as taking blood pressure.

NASA's Robonaut "is one solidly engineered humanoid robot," says Rodney A. Brooks, Ph.D., professor of computer science and engineering and director of the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology in Cambridge, Mass. "We look at it and drool."

meet robonaut

Since the project's inception in 1997, NASA says it has spent nearly $7 million developing the 200-pound Robonaut prototype. The agency plans space tests for 2004 or 2005.

SPEECH

Using IBM's ViaVoice text-to-speech technology, Robonaut replies that it has received the command. Robonaut emits sound through microphones and a speaker inside its head.

IBM Corp.

GRIP COMMAND RECEIVED

SIGHT

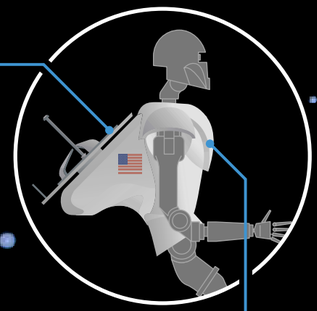
Two Sony color cameras in Robonaut's head function as eyes and allow Robonaut to focus and zoom in on objects. Robonaut can usually determine the proper amount of light in its line of vision automatically; when it can't, the operator can override Robonaut's choices and adjust the zoom, focus and iris controls.

Sony Corp.

BRAIN

Robonaut's brainstem comprises four Power PC chips made by Motorola. Each chip is assigned to a different section of Robonaut: the right arm, left arm, waist and neck, and motor coordination.

Motorola Inc.



BODY

Robonaut's torso is made from 7075 aluminum alloy produced by Alcoa, which is very strong and much lighter than steel, making it easier to send into orbit. An excellent conductor of heat, aluminum also reduces the chance that Robonaut may overheat and have to shut down. Fabric woven out of Teflon and Kevlar fibers, manufactured by DuPont—the same fabric that's on the outside of a spacesuit—covers Robonaut and protects it against flying space debris. Encoders by Hewlett-Packard are in all 47 of Robonaut's joints, as well as ring bearings from Kaydon. Sensors are embedded between each of the limbs and the body so the operator can feel the same external forces as Robonaut.

Alcoa Inc., DuPont, Hewlett-Packard Co., Kaydon Corp., Lockheed Martin Corp., Oceaneering International Inc.

OPERATION

To command Robonaut, the operator wears a virtual-reality helmet and gloves plugged into a Compaq laptop. When the operator moves one of her hands, the laptop transmits the data wirelessly to Power PC chips made by Motorola in Robonaut's brainstem, and Robonaut mirrors the action. The operator also gives Robonaut verbal commands using IBM's ViaVoice software. The software for Robonaut's short-term memory runs on a Compaq workstation.

Compaq Computer Corp., IBM Corp., Motorola Inc.

HAND AND WRIST

Designed to fit inside gloves similar to the type that astronauts wear, Robonaut's hands are compact and weigh five to six pounds, depending on the wiring. Each hand can lift 25 pounds, and the wrist is designed to have the same basic pitch and yaw (or bending and rotating) capability as a human's.

Lockheed Martin Corp., Oceaneering International Inc.

ARM

Each arm contains wires that control the hand, 14 motors and 12 circuit boards. Oceaneering International developed some of the electronics , including a flexible circuit board that wraps around the motors, taking up less space than a traditional hard circuit board. There are 16 sensors in each joint of the arm.

Lockheed Martin Corp., Oceaneering International Inc.

LOWER BODY

Robonaut's single leg plugs into a socket on the space-craft's exterior to stabilize it in zero gravity, freeing up its arms to work. Robonaut doesn't need a second leg; it moves around using the craft's handrails.

DuPont, Hewlett-Packard Co., Lockheed Martin Corp., Oceaneering International Inc.