

EARTHBOUND



Axel, which could be moonbound as early as 2025, undergoes field testing.

JPL-CALTECH/NASA

Robots, Reimagined

Latest generation designed to go where humans can't

By Matt Alderton

PICTURE AN ASTRONAUT. CHANCES are, you probably conjured up the visage of Neil Armstrong or John Glenn. But what about an apelike golem that drives cars and climbs stairs? A mechanical worm that scales glaciers? Or a self-driving hoverboard that rappels caves using its onboard winch?

Even as NASA pursues new frontiers in manned space exploration, roboticists at the agency's Jet Propulsion Laboratory (JPL) near Pasadena, Calif., are diligently working to develop a new generation of robots that can operate independently in all manner of challeng-

ing landscapes. Their long-term vision: autonomous astronauts that can do everything humans do in places humans can't do them.

The primary drivers are safety, practicality and cost. "The cost of sending humans to space is very high because humans require food, air, entertainment, waste disposal and reasonable temperatures," said Aaron Parness, manager of JPL's robotic climbers and grippers group. Robots, by contrast, need only two things: a power source and a communication link. Plus, robots can work 24/7 and withstand months- or yearslong journeys through space and lethal environmental conditions.

A closer look reveals a family of otherworldly robots that portends a new chapter in planetary science:

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**AXEL**

In 2009, Japanese researchers discovered open pits on the moon indicative of tunnels created during the eruption of lunar volcanoes. Because they provide natural shelter from harmful space radiation, these tunnels could be attractive sites for future moon colonies. But first, NASA must explore them, and Axel is made for exactly that task.

Comprising two wheels connected by a single axle, it features a tether that attaches to an anchor — a lunar lander, for example — and unwinds as the spelunking rover lowers itself into a cave. JPL has proposed a Moon Diver mission for NASA's low-cost planetary science program, Discovery; if chosen, Axel could be moonbound as soon as 2025.

**ROBOSIMIAN**

JPL's entry in the DARPA Robotics Challenge — a competition hosted by the Defense Advanced Research Projects Agency from 2012 to 2015 — RoboSimian was conceived for use by emergency responders on Earth but could one day help NASA navigate rough terrain in space, including glaciers, rubble piles and boulder fields.

Because its four articulated appendages are capable of mobility and manipulation, it can climb stairs, open doors, turn wheels and even operate power tools.

LEMUR

JPL's Limbed Excursion Mechanical Utility Robots, or LEMURs, are climbers that look like mechanical spiders. The latest iteration, LEMUR 3, is a quadruped. Its feet feature "micro-spine" grippers that use tiny hooks to attach themselves to rocks. Using artificial intelligence, it can climb, map and analyze surfaces without human intervention. LEMURs have been tested in rocky locations like Death Valley, Calif., and might one day explore Martian caves and craters.

**ICE WORM**

Made of spare RoboSimian parts that were reconfigured and animated using LEMUR software, Ice Worm was inspired by an inchworm and moves by curling and then straightening its body. Instead of trees and bushes, however, Ice Worm's habitat is glaciers and ice caves whose surfaces it scales with grippers that attach using steel ice screws.

Ice Worm has been field tested in glacial caves on Washington's Mount Rainier and Mount St. Helens and eventually could be deployed to volcanic vents on Saturn's ice-covered moon, Enceladus.