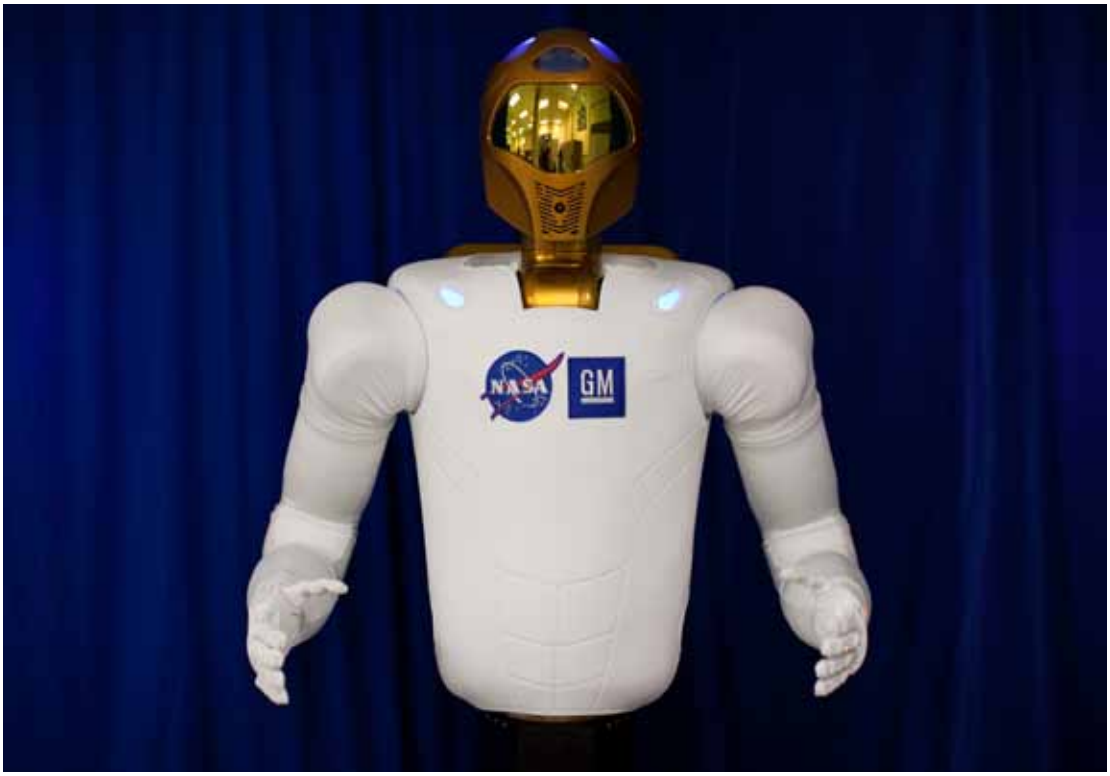
NASAfacts

# Robonaut 2




Almost 200 people from 15 countries have visited the International Space Station, but the orbiting complex has only had human crew members – until now.

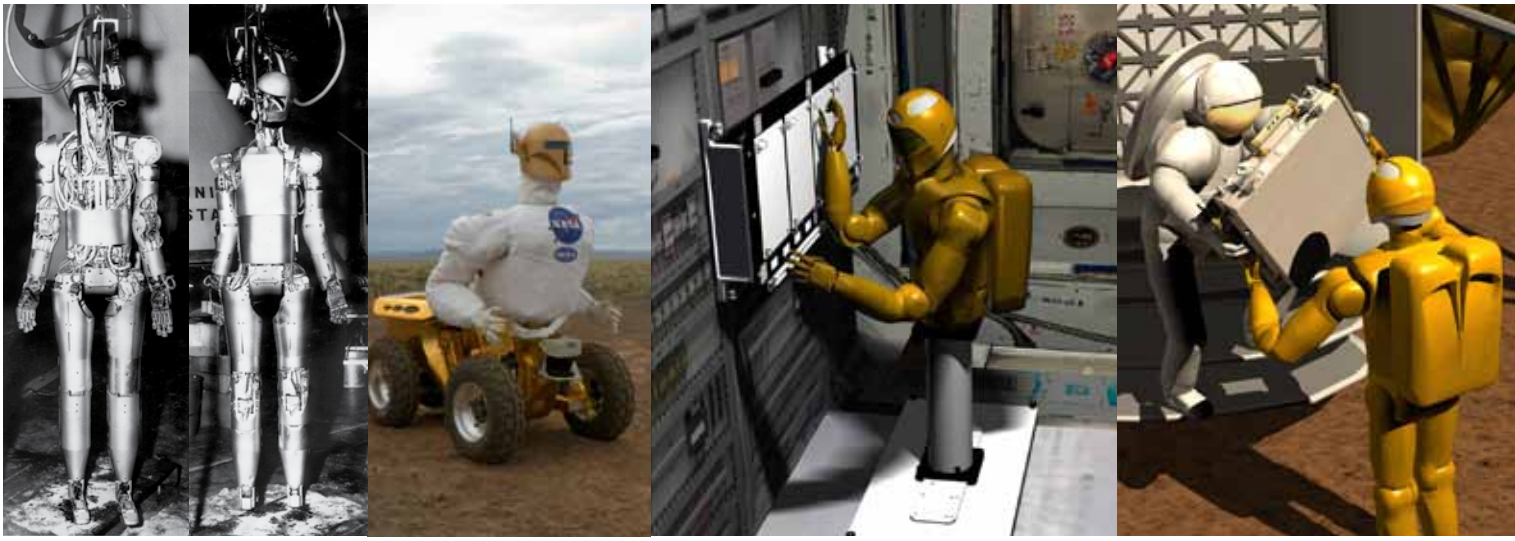
Robonaut 2, the latest generation of the Robonaut astronaut helpers, is set to launch to the space station aboard space shuttle *Discovery* on the STS-133 mission. It will be the first humanoid robot in space, and although its primary job for now is demonstrating to engineers how dexterous robots behave in space, the hope is that, through upgrades and advancements, it could one day venture outside the station to help spacewalkers make repairs or additions to the station or perform scientific work.

R2, as the robot is called, will launch inside the Leonardo Permanent Multipurpose Module, which will be packed with supplies and equipment for the station and then installed permanently on the Unity node. Once R2 is unpacked – likely several months after it arrives – it will initially be operated inside the Destiny laboratory for operational testing, but over time both its territory and its applications could expand. There are no plans to return R2 to Earth.

**History**

Work on the first Robonaut began in 1997. The idea was to build a humanoid robot that could assist astronauts on tasks in which another pair of hands would be helpful or to venture forth to perform jobs either too dangerous for crew members to risk or too mundane for them to spend time on. The result was R1, a human-like prototype of a robot that could perform maintenance tasks or be mounted on a set of wheels to explore the surface of the moon or Mars. Through 2006, R1 performed in numerous experiments in a variety of laboratory and field test environments, proving that the concept of a robotic assistant was valid. The same year, General Motors expressed an interest in hearing about the project. They had been developing their own dexterous robots, and after seeing what NASA had already accomplished, GM proposed teaming up. A Space Act Agreement was signed in 2007 to allow GM and NASA to pool resources and work together on the next-generation Robonaut.

In February 2010, R2 was unveiled – a faster, more dexterous, more technologically advanced humanoid robot than had ever been seen before. Its potential was quickly recognized, and space was made on one of the few remaining shuttle missions to provide it a ride to the space station. There it will make both history, as the first humanoid robot in space, and progress as engineers get their first look at how a humanoid robot actually performs in the absence of gravity.



**Future**

R2's first assignment will be aboard the International Space Station. The conditions aboard the space station provide an ideal proving ground for robots to work shoulder to shoulder with people in microgravity. Once this has been demonstrated inside the station, software upgrades and lower bodies can be added, allowing R2 to move around and eventually work outside in the vacuum of space. This will help NASA understand robotic capabilities for future deep space missions.

As R2 technology matures, similar robots could be sent deeper into space to test the system in more extreme thermal and radiation conditions. Someday, R2 could service communications, weather and reconnaissance satellites, which have direct benefits on Earth.

The next step for robotic capabilities such as R2 would be to explore near-Earth objects, including asteroids and comets, and eventually Mars and Mars' moons. The robot will serve as a scout, providing advanced maps and soil samples, and beginning work on the infrastructure that astronauts would need. The crew that follows would then be much more prepared for the exploration ahead.

This evolution of capabilities for both robotic and human exploration will make a Mars surface mission possible. This human-robotic partnership will allow Mars surface missions to be conducted safely by a smaller crew – without sacrificing mission plans and results.

There is a logical progression for the next generation of space exploration. Our first look at a new destination is through a telescope, then through the eyes of a robotic precursor such as R2, followed by arrival of human explorers. Humans and robots exploring the solar system together will provide greater results than either could achieve alone, enabling an exciting future of new discoveries.

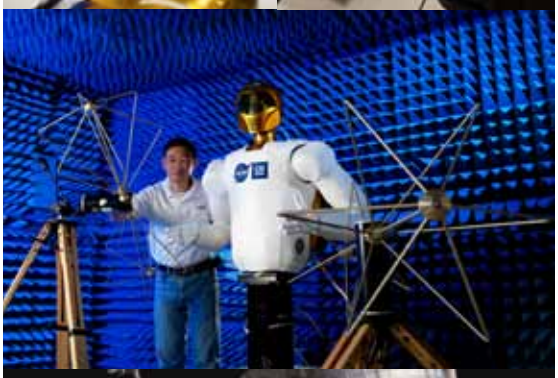
**Upgrading for Space**
R2 was designed as a prototype to be used here on Earth as a way to better understand what would be needed to eventually send a robot to space. However, when R2 was unveiled, the system was so impressive that mission managers decided to go ahead and send it to the space station – but not without a few upgrades. Outer skin materials were exchanged to meet the station's stringent flammability requirements; shielding was added to reduce electromagnetic interference; and processors were upgraded to increase the robot's radiation tolerance. The original fans were replaced with quieter ones to accommodate the station's restrictive noise environment, and the power system was rewired to run on the station's direct current system rather than the alternating current used on the ground.

**Space Readiness Testing**
Before being declared ready to brave the rigors of spaceflight, R2 was put through its paces to make sure the robot could both endure the environment and exist in it without doing damage. Tests were conducted to make sure the robot wasn't too loud, didn't emit electromagnetic waves that would interfere with other station systems, and could run well on the station's power system. It also underwent vibration testing that simulated the conditions it will experience during its launch on board space shuttle *Discovery* to make sure it is ready for the ride.

**Working on the Station**
Initially, R2's primary role on the space station will be experimental. The robot will begin its life in space stationed in the Destiny laboratory, where it will be put through tasks and operations similar to those that it has already performed on Earth, thus allowing engineers to work out issues with operating a dexterous humanoid robot in space. As R2 proves its mettle, the robot may graduate to station maintenance tasks, such as vacuuming or cleaning filters. And with upgrades that would allow it to function in the vacuum of space, it could also perform repairs on the exterior of the station or simply help astronauts as they work outside.

**Control/Operation**
R2 operators have several choices for how to control the robot. Station crew members will be able to operate R2, as will controllers on the ground. However, one of the improvements over the previous Robonaut generation is that R2 doesn't need constant supervision. In anticipation of a future destination in which distance and time delays would make continuous management problematic, R2 was designed to be set to tasks and then carry them through autonomously with periodic status checks.

**Future Frontiers**
Anywhere astronauts go or want to go, R2 will be an asset. The possibilities are endless. R2 can go ahead of its human counterparts to scout out safe locations and make preparations for their arrival. It can work side by side with astronauts once they get there, providing an extra pair of hands for activities that are risky or a waste of valuable crew time. It can be anchored in one place, as is the initial plan for its stay at the station. Or it could be mounted to a mobile base – R1 spent time atop a Segway and a four-wheeled chassis, and legs for R2 are already in development.


**Specifications**

**Materials:** Primarily aluminum with steel, and non-metallics.
**Weight:** 330 pounds
**Height:** 3 feet, 4 inches (from waist to head)
**Shoulder width:** 2 feet, 7 inches

**Sensors:** 350+, total
**Processors:** 38 Power PC Processors
**Degrees of freedom:** 42, total
**Speed:** Up to 7 feet per sec

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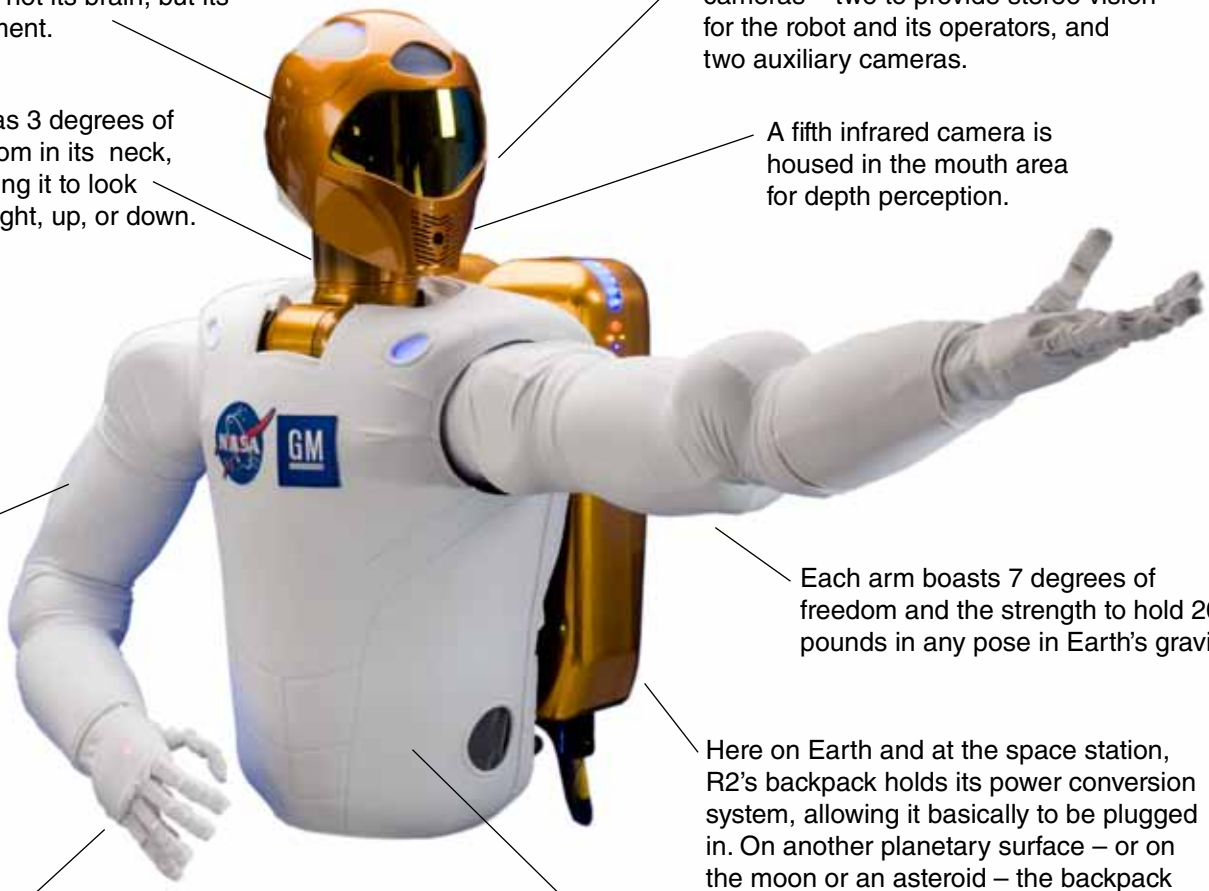
## What Robonauts Are Made Of

A robot meant to work with humans and use human tools begins to look human-like by default. However, R2's head houses not its brain, but its vision equipment.

Behind R2's visor are four visible light cameras – two to provide stereo vision for the robot and its operators, and two auxiliary cameras.

R2 has 3 degrees of freedom in its neck, allowing it to look left, right, up, or down.

A fifth infrared camera is housed in the mouth area for depth perception.




Each arm is approx. 2 feet, 8 inches long, giving the R2 a total wingspan of 8 feet.

Each arm boasts 7 degrees of freedom and the strength to hold 20 pounds in any pose in Earth's gravity.

Here on Earth and at the space station, R2's backpack holds its power conversion system, allowing it basically to be plugged in. On another planetary surface – or on the moon or an asteroid – the backpack would hold the robot's batteries.

Robonaut 2's hands have 12 degrees of freedom – 4 degrees of freedom in the thumb, 3 degrees of freedom each in the index and middle fingers, and 1 each in the ring and pinky fingers. Each finger has a grasping force of 5 pounds.

R2 thinks with its stomach – literally. With its head full of cameras, the only place with enough room for a brain is the robot's torso.

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