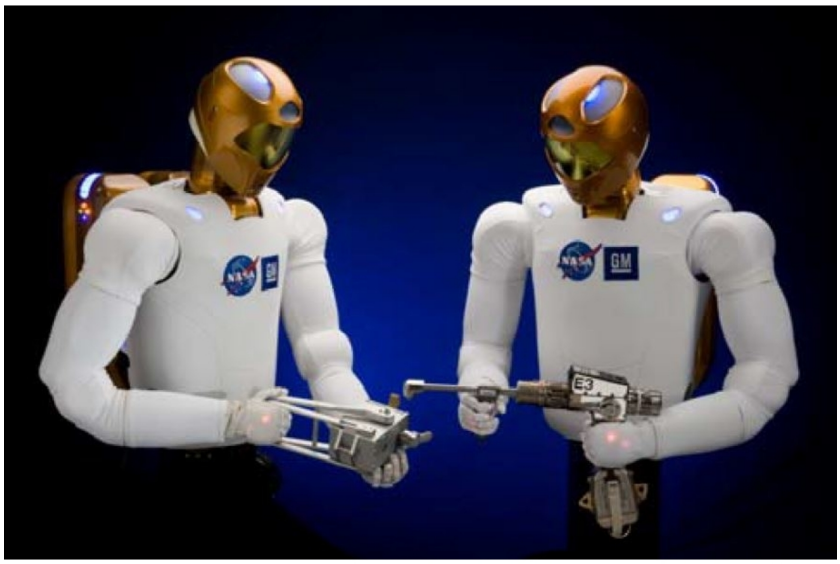


National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

**Robotics, Automation and Control**

# Advanced Humanoid Robotic Hand Technologies

## Cutting-edge systems for humanoid robotics

NASA and General Motors, two organizations at the forefront of robotics, have developed the Robonaut 2 (R2) – a state-of-the-art, dexterous, humanoid robot capable of performing tasks in an automated fashion (or via teleoperation). The technology developed throughout the project represents the cutting edge of autonomous, humanoid robotics. These technologies are available for licensing, both in a modular fashion or as an integrated system, to enhance your robotic products. Please see the Related Links section below for information on additional R2 robotics technologies, including those related to arms, interface/control, and sensor systems.

R2's hand and forearm assembly, the topic of this flyer, is designed to approximate closely the capabilities of the human hand. The assembly is a completely self-contained unit featuring high dexterity, fine force control, and advanced sensing that enables the grasping and actuation of a broad array of tools. Relocation of components (e.g., motors, avionics) to the forearm makes room for increased sensing in the fingers and palm, where it is needed most.

### BENEFITS

- High dexterity: R2's hands are highly dexterous, enabling the robot to perform ergonomically challenging tasks.
- Modularity: The R2 hand and forearm assembly is designed in a modular fashion, enabling rapid replacement of components and sub-assemblies.
- High strength: The unique design enables the assembly to achieve the compact form factor of a human hand while retaining the strength required to work with human tools.
- Self-contained: The dexterous hand plus forearm is a completely self-contained unit with all motors and avionics packaged inside the forearm, reducing the number of conductors required for power and communication.
- Speed: R2's fingers have a top speed of more than 200 mm/sec.

## THE TECHNOLOGY

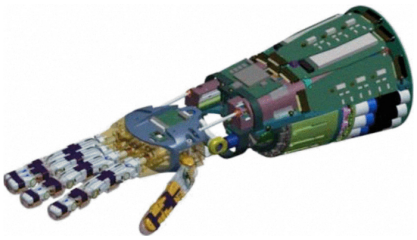
The R2 hand and forearm assembly represents the cutting edge of humanoid robotics technologies. The highly modular design provides significant improvements over prior humanoid robotic hands, especially in the areas of strength, speed, sensing, and ability to approximate human grasps.

Hand, Finger, and Wrist Assembly Design: The robotic humanoid lower arm design (U.S. Patent No. 9,505,134) includes novel robotic finger (U.S. Patent No. 8,562,049), thumb (U.S. Patent No. 8,424,941), and wrist (U.S. Patent No. 8,498,741) assemblies.

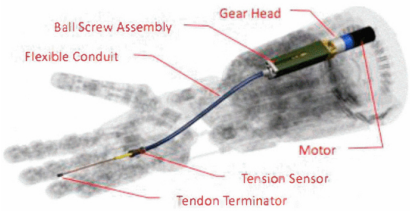
Actuation & Control System: A novel finger actuation system (U.S. Patent No. 8,467,903) – comprised of an actuator, tendon, conduit, tension sensor (U.S. Patent No. 8,371,177), and terminator – is perhaps the primary enabling technology for R2's compact, high performance robotic hand. The actuation system is packaged in the wrist (U.S. Patent No. 8,401,700) and reduces the number of actuators, providing significant space savings. Control systems include methods for tensioning (U.S. Patent Nos. 8,412,376, 8,618,762, & 8,056,423) and controlling torque (U.S. Patent No. 8,565,918) of the tendon-driven robotic fingers. The finger actuation control system (U.S. Patent No. 8,489,239) can operate using force- or position-based control laws.

Tactile System: R2's hands feature an innovative tactile system that grant the robot a sense of touch (e.g., measurement of external contact forces, shear force, and slippage of objects held in the hand) – an important requirement for robots designed to perform complex tasks in an automated fashion. The tactile system is enabled by novel six degree of freedom (DoF) force torque sensors (U.S. Patent No. 7,784,363), three of which are integrated into the fingers (at the proximal, medial, and distal phalanges) and two in the thumb (medial and distal phalanges). A calibration system (U.S. Patent No. 8,265,792) ensures the sensors maintain high accuracy throughout operation.

Autonomous Grasping: A novel grasp assist device (U.S. Patent No. 9,878,452 & 9,067,319) enables reliable, autonomous interaction with a broad range of objects (e.g., tools). A particle filter-based contact state estimation device (U.S. Patent No. 8,280,837) performs object localization and characterization.



The R2 hand and forearm assembly, including avionics.




R2's finger actuation system (U.S. Patent No. 8,467,903).

## APPLICATIONS

The technology has several potential applications:

- Industrial manufacturing & maintenance
- Space exploration
- Personal assistance & caregiving
- Emergency services & operations in hazardous environments
- Repetitive task automation

## PUBLICATIONS

Patent No: 8056423; 8280837; 8,489,239; 9,067,319; 7784363; 8,498,741; 8,467,903; 8,401,700; 8,562,049; 8,857,874; 8,412,376; 8,565,918; 8,265,792; 8,618,762; 9,505,134; 8371177; 8276958; 8060250; 8,511,964; 8,442,684; 8,525,460; 8483877; 8,412,378; D628,609

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NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

MSC-24685-1, MSC-24688-1, MSC-24930-1, MSC-25219-1, MSC-24689-1, MSC-24734-1, MSC-24735-1, MSC-24737-1, MSC-24740-1, MSC-24740-2, MSC-TOPS-102

## More Information

National Aeronautics and Space Administration

**Agency Licensing Concierge**

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