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2014 IN REVIEW

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ISS tools, space exploration show robotics progress

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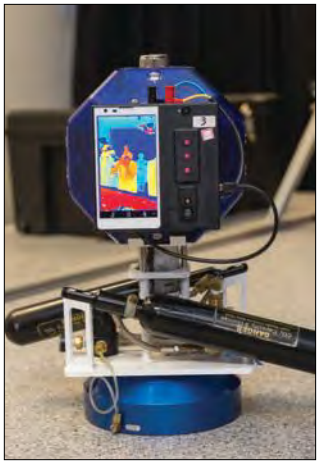
*The **Space Automation and Robotics Technical Committee** works to advance the development of these technologies and their applications to space programs.*

Developments in space automation and robotics this year range from experiments in orbit, to rovers on the Moon and Mars, to future missions still in development. The following highlights represent a small fraction of the latest work in this multidisciplinary field.

In July, NASA launched a Project Tango prototype Android smartphone to the International Space Station as an upgrade to the Synchronized Position Hold, Engage, Reorient Experimental Satellites, or SPHERES, which are bowling-ball-sized robotics that operate inside the station. The Tango phone, which was created by Google's Advanced Technology and Projects division, is capable of 3-D mapping and tracking its own position and orientation in real time. The upgraded robots, called **Smart SPHERES**, could perform a variety of activities inside the station, including interior environmental surveys, inventory and mobile camera work.



NASA Ames/Eric James

Smart SPHERES are Synchronized Position Hold, Engage, Reorient Experimental Satellites equipped with Google's Project Tango smartphone.

Robonaut 2, the humanoid robot that has been on board the ISS since 2011, received a pair of legs this year. While the torso uses a humanoid form factor, the legs offer more degrees of freedom than human legs to allow for increased flexibility in Robonaut 2's activities. The legs can operate both internally and externally to the station, although the torso will require upgrades before it can be used externally. Back on Earth, technologies developed for the legs have also been transitioned into NASA's X1 Robotic Exoskeleton, which has applications for strength augmentation and physical therapy in space as well as on the ground.

Building on their ISS demonstrations, the team behind NASA's **Robotic Refueling Mission** continues to makes strides in on-orbit fuel transfer. In orbit, the tests have used liquid ethanol, a safe stand-in for normal satellite fuel. This year the ground team performed the Remote Robotic Oxidizer Transfer Test, which used the hazardous and corrosive oxidizer of real propellant. These ground tests included the transfer of nitrogen tetroxide at a confined test facility at NASA's Kennedy Space Center in Florida while being controlled by robot operators at the Goddard Space Flight Center in Maryland.

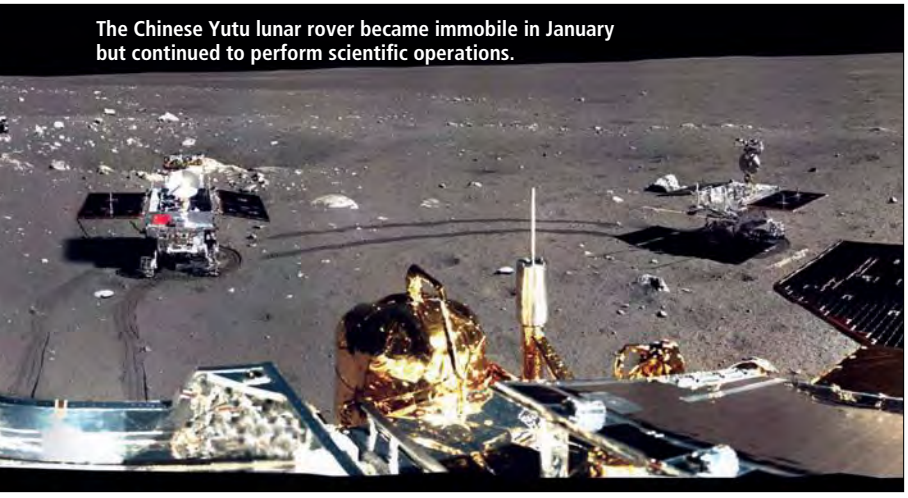
For geosynchronous orbit, DARPA continues to push developments in **orbital robotics** for improved satellite servicing. The servicing and proximity operations technologies needed for the program have the potential to extend the lives and lower the cost of space missions. DARPA is emphasizing three servicing capabilities: high-resolution cooperative inspection, including difficult-to-reach locations; orbit adjustment assistance, to add flexibility to geosynchronous fleet operations; and mechanical assistance with deployment anomalies.

On Aug. 5, NASA's **Curiosity rover** marked its second anniversary on Mars. The rover continues to traverse the surface and search for signs of conditions that might support life, and it has found more evidence of past water on Mars near Gale Crater. The rover continues to study the surface and has reached Mount Sharp, its destination since landing.

This year marks the 10th anniversary of the Mars Exploration Rover mission. With an odometer reading over 25 miles, the **Opportunity rover** has broken the record for the longest distance traveled on an extraterrestrial surface. The Soviet Union's Lunokhod 2 lunar rover previously held the record at 24.2 miles. The Opportunity rover continues to perform science on the surface of Mars today.

A new player has entered the scene of planetary surface robotics. In December 2013, the Chinese Chang'e 3 spacecraft landed on the Moon and released a small rover called **Yutu**, or "Jade Rabbit." The rover drove about 110 meters before becoming immobile in late January, but continued to perform science operations while stationary. The science payload on board Yutu included a ground-penetrating radar, two spectrometers and several cameras. The mission lasted about six months and was the first soft landing and roving mission to the Moon since 1976.

The Chinese Yutu lunar rover became immobile in January but continued to perform scientific operations.



CNSA/ChinaNews/Ken Kremer/Marco Di Lorenzo