Space station SPHERES run circles around ordinary satellites

February 17 2014, by Laura Niles

NASA astronaut Thomas Marshburn tests the SPHERES-Vertigo investigation hardware, which resembles eye goggles, as it flies aboard the International Space Station. Credit: NASA

(Phys.org) —These are, in fact, the droids that NASA and its research partners are looking for. Inspired by a floating droid battling Luke Skywalker in the film Star Wars, the free-flying satellites known as Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) have been flying aboard the International Space Station since Expedition 8 in 2003. Although there have been numerous SPHERES investigations held on the orbiting laboratory, four current and upcoming SPHERES projects are of particular significance to robotics engineers, rocket launch companies, NASA exploration and anyone who uses communications systems on Earth.

The SPHERES-Vertigo, Department of Defense (DOD) SPHERES-Rings, SPHERES-Slosh and SPHERES-Inspire II investigations all use the existing SPHERES space station facility of these self-contained satellites. Powered not by an astronaut's use of the Force, but by AA batteries, the satellites act as free-flying platforms that can accommodate various mounting features and mechanisms in order to test and examine the physical or mechanical properties of materials in microgravity. Each satellite is an 18-sided polyhedron and is roughly the size of a soccer ball. NASA's Ames Research Center in Moffett Field, Calif., operates and maintains the SPHERES research facility aboard the space station, which is funded by the Human Exploration and Operations Mission Directorate at NASA Headquarters in Washington.

SPHERES provide a unique low risk, low-cost, long-term microgravity research facility that supports quick-reaction testing of technologies that can be repeated numerous times. Alvar Saenz Otero, Ph.D., associate director and SPHERES lead scientist at the Massachusetts Institute of Technology (MIT) Space Systems Laboratory describes the reusability of SPHERES for multiple microgravity investigations by saying, "if anything goes wrong, reset and try again!"

Operating intermittently since February 2013, the SPHERES Visual Estimation and Relative Tracking for Inspection of Generic Objects (SPHERES-Vertigo) investigation uses what looks like eye goggles and other new hardware and software on multiple satellites during testing. The purpose of the study is to build 3-D models of a target using mapping algorithms and computer vision-based navigation. These additions to the satellites help researchers create 3-D maps of a previously unknown object for navigation by flying the SPHERES in a path around that object while taking photos.

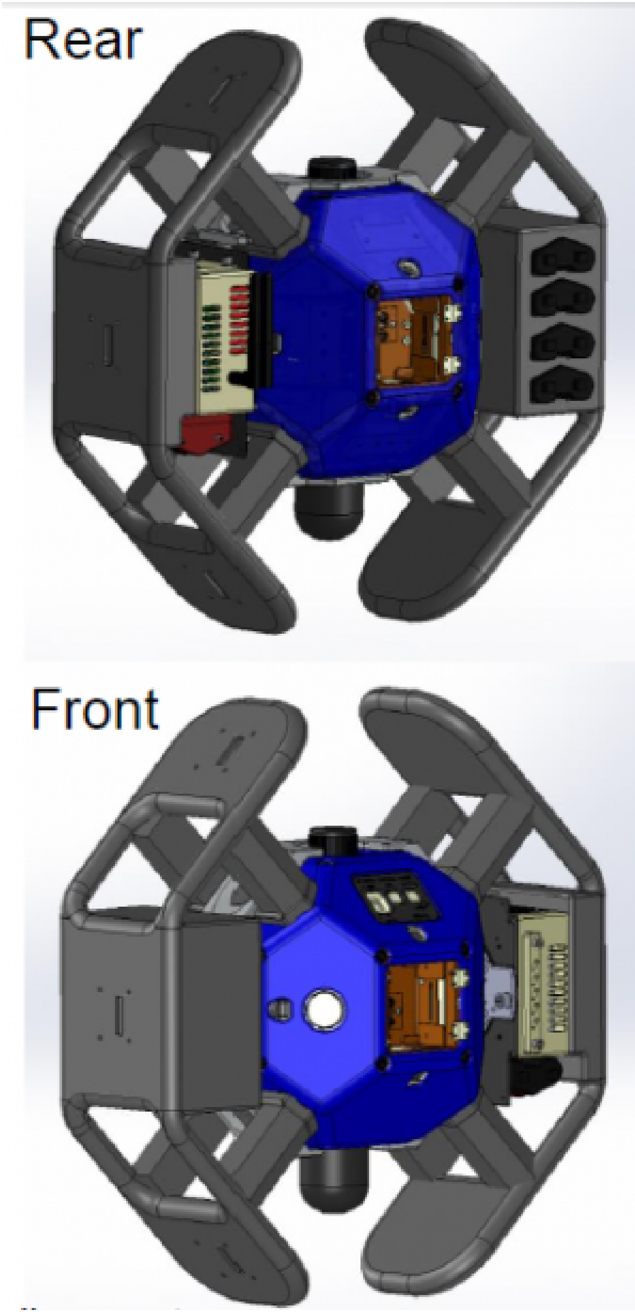
Brent Tweddle, a postdoctoral associate with the MIT Space Systems Laboratory, said the SPHERES-Vertigo project differs from previous SPHERES experiments by "adding a pair of stereo cameras, which see, perceive and understand their world visually and can communicate with satellites using Vertigo goggles." The goggles act "like their own little intelligence block that sticks on the front end of the SPHERES and allows them to see the rest of the world that they want to navigate through," explained Tweddle.

First, the SPHERES use their updated hardware and software to construct a 3-D model of a target object. Then, the satellites test their skills to perform relative navigation using only sensory reference to the 3-D model.

Imaging from projects like Vertigo could help refurbish old satellites by determining and mapping the specifications of the old satellites and repairing them as they orbit Earth. Other applications include NASA's future mission of visiting an asteroid, where thorough understanding of the size, shape and motion of an asteroid is necessary to navigate around it as it travels through space. Further, as robots become more autonomous, they will need a pair of eyes, similar to Vertigo, to provide them with navigational capabilities.

The DOD SPHERES-Rings investigation is the first demonstration of electromagnetic formation flight in microgravity, as well as of wireless power transfer in space. The study installs highly advanced rings to existing SPHERES. The crew places the rings around an individual satellite, consisting of resonant coils, coil housing with fans, batteries and support structure hardware. The Rings project demonstrates the use of electromagnetic coils to maneuver individual SPHERES with respect to one another. The current running through the ring of coils controls the satellites, so that two ring-outfitted SPHERES are able to attract, repel and rotate.

"Using electrically-generated forces and torques is preferable to using fuel, since electricity can be generated by solar panels, but once fuel is expended, the mission is generally over," explained Kathleen Riesing, a graduate student with the MIT Space Systems Laboratory. The software used to control the rings will also demonstrate wireless power transfer, where one satellite sends power to another.

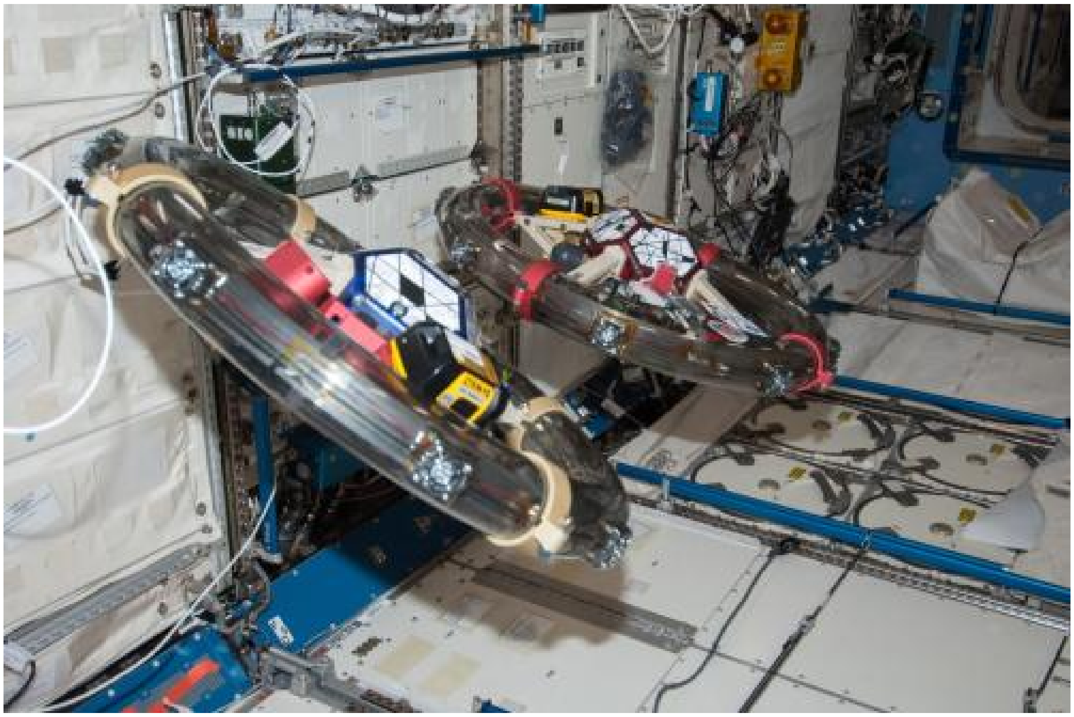


This computer-aided design illustrates the SPHERES-Inspire II Halo interface, which adds processing power and data handling capabilities to SPHERES for testing scenarios aboard the International Space Station. Credit: MIT/Space Systems Laboratory

Research goals for SPHERES-Rings include enhanced attitude control performance between separate satellites and the possibility of more efficient power transfer at a distance. Adding an efficient way to transfer power between SPHERES may alleviate the need for alternate power sources. The wireless power transfer experiment establishes the hardware necessary for potential future powering of space and urban robotics and enhanced communications systems in space, on land or underwater.

The new SPHERES-Slosh investigation launched aboard Orbital Sciences Corporation's first Cygnus cargo resupply spacecraft to the space station on Jan. 9. The investigation was named for the sound of liquids sloshing. SPHERES-Slosh seeks to understand how fluids move inside containers during long-duration flight in microgravity. The study will demonstrate how applied external forces impact the contained fluids. The goal is to simulate how rocket fuels move around inside their tanks, as in response to motor thrusts used to push a rocket through space. The study of the physics of liquid motion in microgravity is important because Earth's most powerful rockets use liquid fuels to take satellites and other spacecraft into orbit.

SPHERES-Slosh externally mounts a tank between two of the small satellites. The pair then flies around inside the space station, creating the "slosh" scenario. The tank geometry simulates a launch vehicle propellant tank and the maneuvers replicate those of real vehicles.

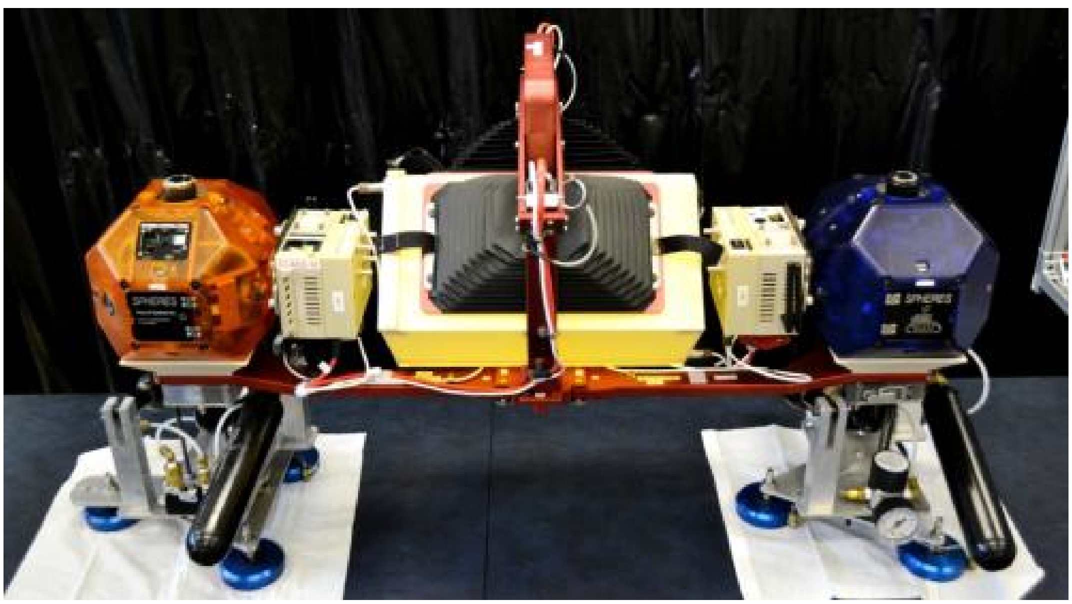


DOD SPHERES-Rings fly freely on the International Space Station during demonstration testing of electromagnetic formation flight and wireless power transfer in microgravity. Credit: NASA

"I believe the results from this experiment can help rocket launch companies design better tanks and control systems which will make a significant impact," said Stephen Gaddis, program manager of the Space Technology Mission Directorate's Game Changing Development Program at NASA's Langley Research Center in Hampton, Va. Having a deeper understanding of rocket propellants may lower the cost of industry and taxpayer-funded satellite launches by improving safety and fuel efficiency.

Coming mid-2014, the SPHERES-Inspire II investigation adds a series of universal docking ports and a series of Halo interfaces to existing SPHERES on the space station. The Halos consist of six ports each and surround the small satellites, as the name would suggest. These Halos and ports expand SPHERES processing power and data handling capabilities for extensive testing scenarios. The SPHERES-Vertigo "eye goggles" can be attached to the Halo to provide vision-based navigation.

"The testing scenarios that are planned will focus on resource aggregation and satellite reconfiguration as a risk reduction platform for the types of satellite maneuvers expected to be performed by satellites for the Defense Advanced Research Projects Agency (DARPA) Phoenix mission," said David Sternberg, a graduate student with the MIT Space Systems Laboratory.



Pill-shaped tanks partially filled with water are attached to the small satellites for the SPHERES-Slosh investigation aboard the International Space Station to simulate the movement of rocket fuels as they slosh inside the tanks.
Credit: Florida Institute of Technology/Dr. Daniel Kirk

The DARPA Phoenix mission is working to develop small "satlets" that can robotically attach to aging or non-functioning satellites in geosynchronous orbit approximately 22,000 miles above Earth. This creates new space systems at a reduced cost.

With every new hardware addition to SPHERES, significant advancements are made in robotics proficiencies, and one day, older or non-functional satellites will be repaired or refurbished in orbit. The science fiction of robotic droids buzzing around to equip and repair spacecraft and space travelers is no longer just the fantasy of Star Wars. Rather, the use of robotic capabilities is fast becoming more of a reality thanks to these free-flying SPHERES.

Provided by NASA

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