Slosh experiment designed to improve rocket safety, efficiency

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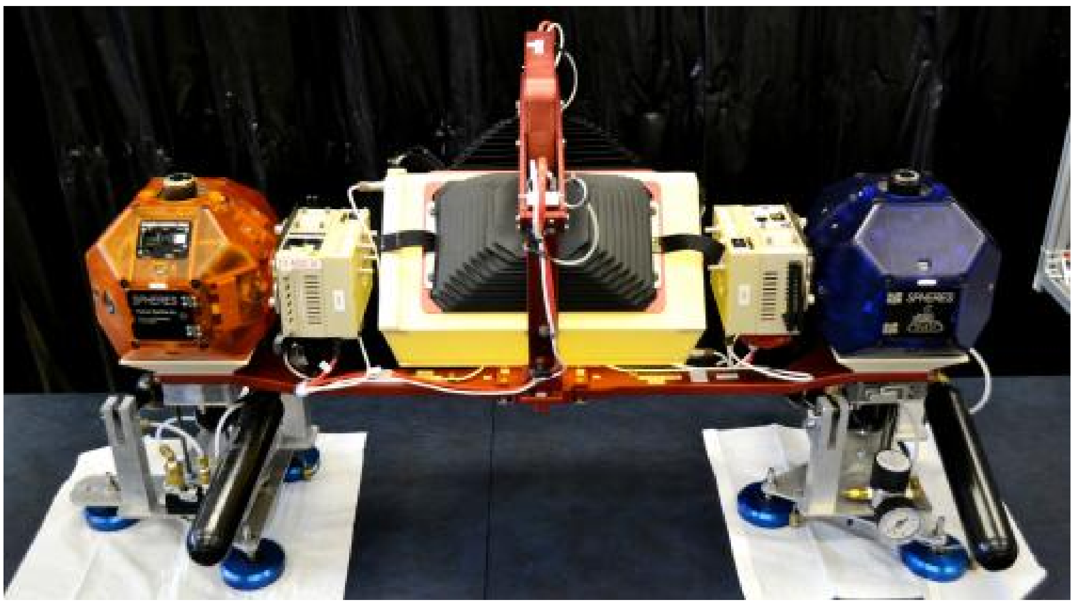

The SPHERES robots will be attached at opposite ends of a metal frame. In the center of the frame is a clear plastic 18-inch by eight-inch pill shaped tank that is partially filled with green colored water. A pair of high resolution cameras will record the movement of the liquid inside the tank as the experiment is pushed around by the SPHERES robots. Additionally, several inertial measurement units will accurately record the position of the experiment as it moves within the space station. Credit: Florida Institute of Technology/Dr. Daniel Kirk

Since Robert Goddard's first launch of a liquid propellant rocket in 1926, experts have worked to perfect engine propulsion systems. As launch vehicles have grown in size, fuel and oxidizer tanks have become more complex resulting in unexpected changes in thrust, potentially endangering flight crews and mission success. A team of scientists and engineers at NASA's Kennedy Space Center in Florida is now studying how to better understand this phenomenon and reduce its potential impacts to flight safety.

As the large Saturn V rockets were being tested for the Apollo Program in the late 1960s, up and down oscillations of the launch vehicle, called the "pogo" effect, sometimes resulted in potentially dangerous variations in engine performance. The anomaly resulted in changes in acceleration due to differences in fuel pressure and flow rates, possibly placing additional stresses on the vehicle.

According to Paul Schallhorn, Ph.D., chief of NASA's Environments and Launch Approval Branch of Kennedy's Launch Services Program, larger rockets are now expected to operate in more varied environments from high g loads to zero gravity.

"The issues we see now go well beyond the pogo effect," he said. "Upper stages are now firing multiple times and operating in microgravity after reaching space. We need to have a better understanding of how propellants 'slosh' around in their tanks so we can compensate for changes in a rocket's performance."

The effort to better understand how propellants slosh in their tanks arose with a Delta IV launch during 2006.

"Plans called for an aggressive maneuver by the upper stage to position the satellite in orbit," Schallhorn said. "As we asked questions about predicting how the propellants would move around in the tanks, it was apparent no one knew how good our data was. There just wasn't that much test information available."

The current inability to accurately predict fuel and oxidizer behavior can result in unnecessary caution, requiring extra propellant to be added along with additional helium for tank pressurization. A better understanding of fluid slosh could not only decrease this uncertainty, but increase efficiency, reduce costs and allow additional payloads to be launched.

Schallhorn is now serving as principal investigator for research to gain more reliable data on the slosh anomaly. To further understand liquid propellant slosh, engineers with NASA have teamed up with researchers at the Florida Institute of Technology and the Massachusetts Institute of Technology.

Some assembly required. The hardware for the Slosh experiment was developed by students at the Florida Institute of Technology. Once on board the space station, astronaut crew members will assemble the package. Credit: Florida Institute of Technology/Dr. Daniel Kirk

The Slosh Project is funded by NASA Space Technology Mission Directorate's Game Changing Development (GCD) program. GCD is designed to investigate innovative ideas and approaches that have the potential to revolutionize future space missions and provide solutions to significant national needs.

"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, director of the Game Changing Development Program.

A key element of the team's studies will be an experiment involving the Synchronized Position Hold, Engage, Reorient, Experimental Satellites, or SPHERES, which are already operational on the space station. The Slosh experiment will be carried to the International Space Station aboard a Cygnus spacecraft atop an Antares rocket. This will be a part of the Orbital 1 Commercial Resupply Services flight scheduled to lift off from the Mid-Atlantic Regional Spaceport at NASA's Wallops Flight Facility in Virginia in December 2013.

The hardware for the Slosh experiment was developed by students at Florida Tech. Once on board the space station, astronaut crew members will assemble the package. The SPHERES will be attached at opposite ends of a metal frame. In the center of the frame is a clear plastic 18-inch by eight-inch pill-shaped tank that is partially filled with water.

The SPHERES are bowling-ball-sized robots that use small carbon dioxide gas thrusters to maneuver as they free-float inside the space station. They operate on a set of well-defined instructions for various maneuvers. Each SPHERES is self-contained with power, propulsion, computers and navigation equipment operated by a station crew member using a laptop computer.

"Modern computer models try to predict how liquid moves inside a propellant tank," said NASA's Brandon Marsell, co-principal investigator on the Slosh Project. "Now that rockets are bigger and going farther, we need more precise data. Most of the models we have were validated under 1 g conditions on Earth. None have been validated in the surface tension-dominated microgravity environment of space."

This data could prove crucial as NASA continues designing the Space Launch System, a powerful new rocket which could take astronauts farther into space than ever before. It also will help the Launch Services Program analyze increasingly challenging robotic missions. The Slosh Project will aid in knowing the location of the liquid inside the propellant tanks, increasing efficiency and vehicle performance.

The SPHERES-Slosh experiment to be carried to the International Space Station aboard a Cygnus spacecraft like this one launched atop an Antares rocket on Sept. 18, 2013. The Orbital 1 Commercial Resupply Services flight is scheduled to lift off from the Mid-Atlantic Regional Spaceport at the Wallops Flight Facility in Virginia in December 2013. Credit: NASA

Scientists have had success accurately validating how propellants perform on the ground. However, in the absence of gravity, the physics changes drastically and liquids behave differently.

NASA's Jacob Roth, also a co- principal investigator on Slosh, explains that the reactions of fluids will be photographed by a pair of high-resolution cameras that will record the movement of the liquid inside the tank as the experiment is pushed around by the SPHERES robots.

"The free-floating experiment will perform typical upper-stage vehicle maneuvers within the station," he said. "The liquid will be photographed and measured with the data transmitted back to Earth for use in validating current computational fluid dynamics models."

Additionally, several inertial measurement units will accurately record the position of the experiment as it moves within the space station. While water has some different properties than rocket fuels and oxidizers, Schallhorn says it should be close enough.

"We've tested water, liquid hydrogen, hydrazine and other propellants in 1 g and aboard a zero-g aircraft" he said. "In this case we'll use water because of the inherent hazards of cryogenic and hypergolic fuels. By comparing the actions of water in microgravity to what we see in 1 g, we can calculate what that would mean for actual rocket propellants."

The data will be used to check computer simulations currently predicting rocket performance, ultimately leading to launch vehicles and spacecraft that are more reliable, cost effective and safer.

Provided by NASA/Johnson Space Center

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