# NASA tests new technologies for robotic refueling

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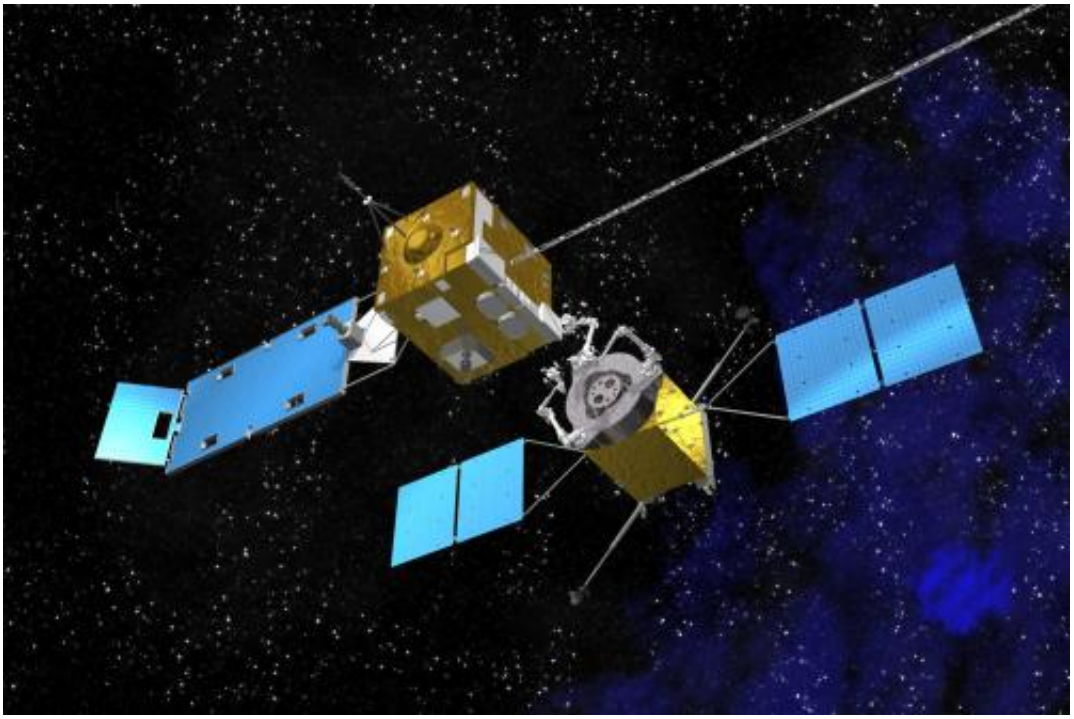

In space, a robot servicer could use propellant transfer technologies to extend the life of orbiting satellites (depicted, artist's concept). Credit: NASA

(Phys.org) —It's corrosive, it's hazardous, and it can cause an explosion powerful enough to thrust a satellite forward in space. Multiple NASA centers are currently conducting a remotely controlled test of new technologies that would empower future space robots to transfer this dangerous fluid—satellite oxidizer—into the propellant tanks of

spacecraft in space today.

Building on the success of the International Space Station's landmark Robotic Refueling Mission (RRM) demonstration, the ground-based Remote Robotic Oxidizer Transfer Test (RROxiTT) is taking another step forward in NASA's ongoing campaign to develop satellite-servicing capabilities for space architectures and human exploration.

On Earth, RROxiTT technologies could one day be applied to robotically replenish satellites before they launch, keeping humans at a safe distance during an extremely hazardous operation.

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## Building on the Past to Set the Stage for the Future

In January 2013, RRM demonstrated that remotely controlled robots—using current-day technology—could work through the caps and wires on a satellite fuel valve and transfer fluid into existent, orbiting spacecraft that were not designed to be serviced. To meet the safety requirements of space station, ethanol was used as a stand-in for satellite fuel. For the team that conceived and built RRM, the Satellite Servicing Capabilities Office (SSCO) at NASA's Goddard Space Flight Center in Greenbelt, Md., the successful conclusion of this refueling demonstration was not the end of their work—only the beginning.

"We were immensely pleased with RRM results. But doing more was always part of the plan," says Benjamin Reed, deputy project manager of SSCO. "There were certain aspects of satellite refueling that couldn't be demonstrated safely while we were using space station as a test bed – aspects that we chose to defer to a later test date. RROxiTT is the next step in that technology development."

Taking lessons learned from RRM, the SSCO team devised the ground-based RROxiTT to test how robots can transfer oxidizer, at flight-like pressures and flow rates, through the propellant valve and into the mock tank of a satellite that was not designed to be serviced in space.

"No one has ever attempted this type of oxidizer transfer before," says Marion Riley, the SSCO test manager for RROxiTT. "Like any NASA-sized challenge, we had to figure out—and at times, create—the right set of technologies and procedures to get the job done. Testing on the ground helps us know we're on the right track."

At the heart of RROxiTT's complexity is the nature of the dangerous substance the robot is handling. Oxidizer—namely nitrogen tetroxide—is a chemical that, when mixed with satellite fuel, causes instant combustion that provides thrust (motion) for a satellite. Oxidizer is contained within a satellite tank at intense pressures, up to 300 pounds per square inch (about 20 times atmospheric pressure). Toxic, extremely corrosive and compressed, it requires special handling and a unique set of technologies to transfer it.

From his control center at NASA Goddard, RROxiTT lead roboticist Alex Janas commands an industrial robot more than 800 miles away at Kennedy Space Center (robot shown here, right, at NASA Goddard before it was shipped to Kennedy).

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## A Collaborative Effort to Build Space Capabilities

To tackle key areas of these challenges, the Goddard SSCO team approached Kennedy Space Center (KSC) to work with them as an integrated part of the SSCO team. With hundreds of spacecraft launches under their belts, the KSC team understands what it takes for humans to fuel satellites safely on the ground. They were eager to bring this wealth of knowledge to a new, robotic-based arena.

"The task of flowing oxidizer from one tank to another in a controlled and safe manner requires a complex system between the tanks," says Brian Nufer, the lead fluids engineer of the SSCO KSC team. "To design

this complex system, the joint GSFC and KSC team was required to develop new technologies and modify existing technologies not originally intended to be used for this type of application and operating environment."

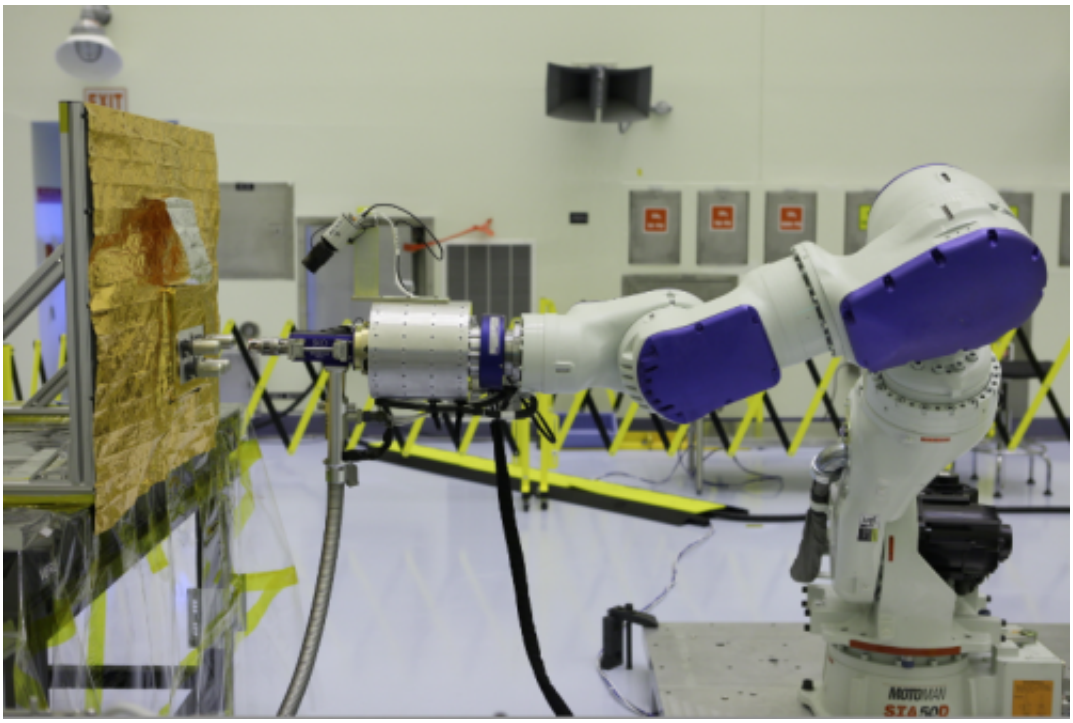
KSC designed, developed, and tested a unique, flight-like Propellant Transfer System tailored to deliver oxidizer, complete with an innovative, highly accurate metering system and a specialized seal-less pump the size of a roll of quarters. Attached to the output of the system is an advanced flexible hose.

To complete the hardware suite, the Goddard team built a specially designed "Oxidizer Nozzle Tool" that leverages RRM experience. When this collection of new technologies is connected to the RROxiTT industrial test robot, the complement turns into a fluid-transferring system that can deliver life-extending oxidizer into a representative satellite tank.

Located at Kennedy but commanded from Goddard, the RROxiTT industrial robot mimics how future space robots could transfer oxidizer to satellites that were not designed to be serviced.

## Robot Technicians

For Alex Janas, lead roboticist for RROxiTT, the hardest part of the test is not creating the technologies—it is running the test when he is half a country away.



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When Janas steps up to his console at Goddard in Maryland to drive the RROxiTT robot, he does not have a robot, tool or a propellant pump in sight. Just a few coworkers are there to provide support as needed, and from the sidelines, a handful of excited onlookers wishing him luck. Every other piece of hardware for the test is located more than 800 miles away at the Payload Hazardous Servicing Facility at KSC in Florida.

With the cameras on the robot to guide him and supported by innovative software, Janas uses a joystick and keyboard to mate the robot's tool to the satellite valve so the oxidizer transfer can take place.

"Conducting the test remotely adds an extra layer of complexity which ultimately helps us," says Janas. "It mimics what we would encounter

during real robotic servicing in space, where the human robotic operator would be on the ground, far away from the client that his or her robot is servicing."

## Looking to the Future

The servicing capabilities SSCO is developing could greatly expand options for government and commercial operators in the future, providing new ways to recover from anomalies or prolong the lifespans of their satellites. Technologies needed for servicing—including autonomous rendezvous and docking systems, advanced robotic tools, and propellant transfer systems, among others—can help the Agency on its path to extended human exploration, observatory servicing, the on-orbit assembly of large space structures, and perhaps even planetary defense.

By executing RROxiTT, SSCO aims to gain invaluable data about the performance of their new propellant transfer technologies and the telerobotic operational procedures developed to date. Results will help the team to resolve discovered anomalies and advance the system in preparation for flight. With RROxiTT off their checklist, SSCO will focus on advancing additional technologies to transfer other propellants commonly used by satellites, such as Xenon used in solar electric propulsion systems.

These new space technologies could also make ground operations safer one day. "Instead of having a human fuel a satellite prior to its launch – a hazardous procedure – perhaps a robot could do it instead, with humans controlling from a safe distance," said Reed.

Frank Cepollina, veteran leader of the five servicing missions to the Hubble Space Telescope and the associate director of SSCO, sees RROxiTT and the satellite-servicing technology development campaign

as an ongoing extension of NASA's capabilities in orbit.

"NASA is constantly inventing, testing and refining cutting-edge technologies—always with the goal of expanding our reach in space and eventually transporting humans to Mars," Cepollina says. "Every advancement we make, every capability brought into existence by the application of ingenuity and innovation, builds our confidence and is a step in the right direction. We're excited to be pushing the next evolution of technologies in this field. It's a great time to be a part of NASA."

Provided by NASA