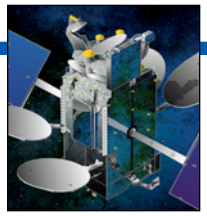
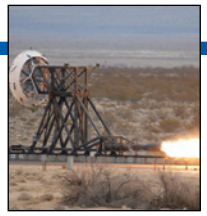
National Aeronautics and
Space Administration

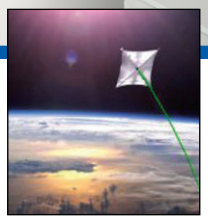
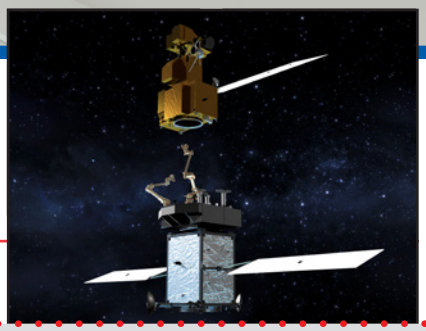
Technology Demonstration Missions Program

The Bridge

Spring–Summer 2016





In this artist's rendering, the Restore-L servicer extends its robotic arm to grasp and refuel a client satellite on orbit. (Image: NASA)

NASA's Restore-L Mission Set to Demonstrate Crosscutting Technologies

Disruptive technologies often have changed the course of history, breaking the status quo and unlocking possibilities yet to be imagined. Building on a history of upgrading and maintaining assets in space, NASA's new Restore-L project is developing an unprecedented capability while creating a paradigm shift: robotic satellite servicing.

In May, NASA officially moved forward with plans to execute the ambitious, technology-rich Restore-L mission, an endeavor to launch a robotic spacecraft in 2020 to refuel a live satellite. The mission – the first of its kind in low-Earth orbit – will demonstrate that a carefully curated suite of satellite-servicing technologies are fully operational.

The new Technology Demonstration Mission project, funded by NASA's Space Technology Mission Directorate, is led by NASA's Goddard Space Flight Center.

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STMD Headlines NASA's First-ever Appearance at Consumer Electronics Show

At the Consumer Electronics Show, the high-profile technology expo held in Las Vegas in early 2016, Turkesa Lanier, center, a representative of the Technology Demonstration Missions Program Business Office, shows off NASA's new Google Cardboard app, "Technology Drives Exploration" to a steady stream of booth visitors. Created by TDM's parent organization, the Space Technology Mission Directorate, the app – designed to support Android and iOS devices, explores technologies that will enable human explorers to land safely on Mars and live and work on the Red Planet for extended periods of time. NASA and STMD/TDM were among an estimated 3,600 exhibitors demonstrating new products and services to as many as 170,000 expo attendees. The Consumer Electronics Show has been held annually in Las Vegas since 1998. (Image: NASA/TDM/Keyke Reed)

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"NASA's Space Technology Mission Directorate rapidly develops, demonstrates and infuses revolutionary, high-payoff technologies," said Jim Reuter, deputy associate administrator for programs in STMD. "Restore-L embodies these goals and we look forward to realizing its potential."

The project's current candidate client is Landsat 7, a government-owned satellite in low-Earth orbit.

The Restore-L mission also will test crosscutting technologies that have applications for several critical upcoming NASA missions. As the Restore-L servicer rendezvous with, grasps, refuels and relocates a client spacecraft, NASA will tick important items off its technology checklist–putting humans ever closer to Mars exploration.

Restore-L technologies include an autonomous relative navigation system with supporting avionics and dexterous robotic arms and software. The suite is completed by a tool drive that supports a collection of sophisticated robotic tools for spacecraft refueling and a propellant transfer system that delivers measured amounts of fuel at the proper temperature, rate and pressure.

Future candidate applications for Restore-L technologies include on-orbit manufacturing and assembly, propellant depots, observatory servicing and orbital debris management. NASA also will apply several Restore-L technologies to its refuelable Asteroid Redirect Mission, leveraging Restore-L's autonomous rendezvous system, dexterous robotics and software, avionics and more.

Boosting commercial spaceflight

NASA's second, equally important objective for Restore-L is to infuse its technologies to domestic commercial entities to help jumpstart a new, competitive industry in robotic satellite servicing, an area ripe with possibility.

"Restore-L effectively breaks the paradigm of one-and-done spacecraft," said Frank Cepollina, veteran leader of the five crewed servicing missions to the Hubble Space Telescope. Cepollina now serves as the associate director of Goddard's Satellite Servicing Capabilities Office, the team that first conceived and is now developing Restore-L.

"It introduces new ways to robotically manage, upgrade and prolong the lifespans of our costly orbiting national assets. By doing so, Restore-L opens up expanded options for more resilient, efficient and cost-effective operations in space," Cepollina said.

Currently, spacecraft launch with a finite amount of fuel, their lifespans restricted by the amount of propellant they can carry. A refueling capability in space, offered by future propellant-delivery spacecraft similar to Restore-L, could provide satellite owners the ability to manage, maintain and save their most valuable assets in space. Restore-L also could help decrease the risk for future servicing ventures and establish a global precedence for safe rendezvous operations in orbit.

Looking to the future

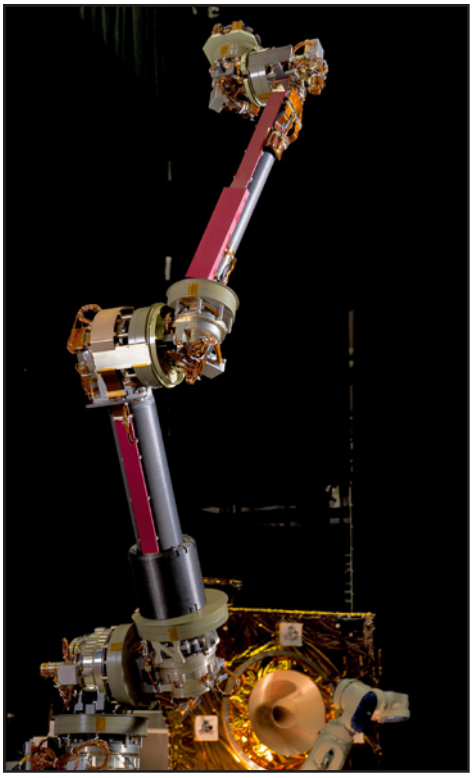
Restore-L technologies are foundational for other ambitious objectives beyond refueling. "You cannot entirely forecast how the aerospace community will run with new, capability-building servicing technologies, but we can predict likely short-term innovations," said Benjamin Reed, deputy project manager for Goddard's Satellite Servicing Capabilities Office.

"With robotic servicing on the table, satellite owners can extend the lifespan of satellites that are running low on fuel, reaping additional years of service–and revenue–from their initial investment," Reed said. "If a solar array or a communications antenna fails to deploy, a servicer with inspection cameras and the right repair tools could help recover the asset that otherwise would have been lost. The loss of an anticipated revenue or data stream can be devastating."

Servicing capabilities could help satellite owners better manage their space assets in innovative ways. This could include launching a spacecraft with a half-empty fuel tank and allotting the saved weight to mission-specific instruments. "Dependable robotic satellite servicing unlocks countless opportunities," Reed said.

The TDM Program Office soon will launch a Restore-L web presence. Watch *The Bridge* for updates.

This article is abridged from a NASA news feature by Adrienne Alessandro, a Goddard project support specialist and InuTeq contractor.



An engineering design unit of the NASA Servicing Arm, to be used for the Restore-L mission, stands in the Robotics Operations Center at Goddard. (Image: NASA/GSFC/Chris Gunn)

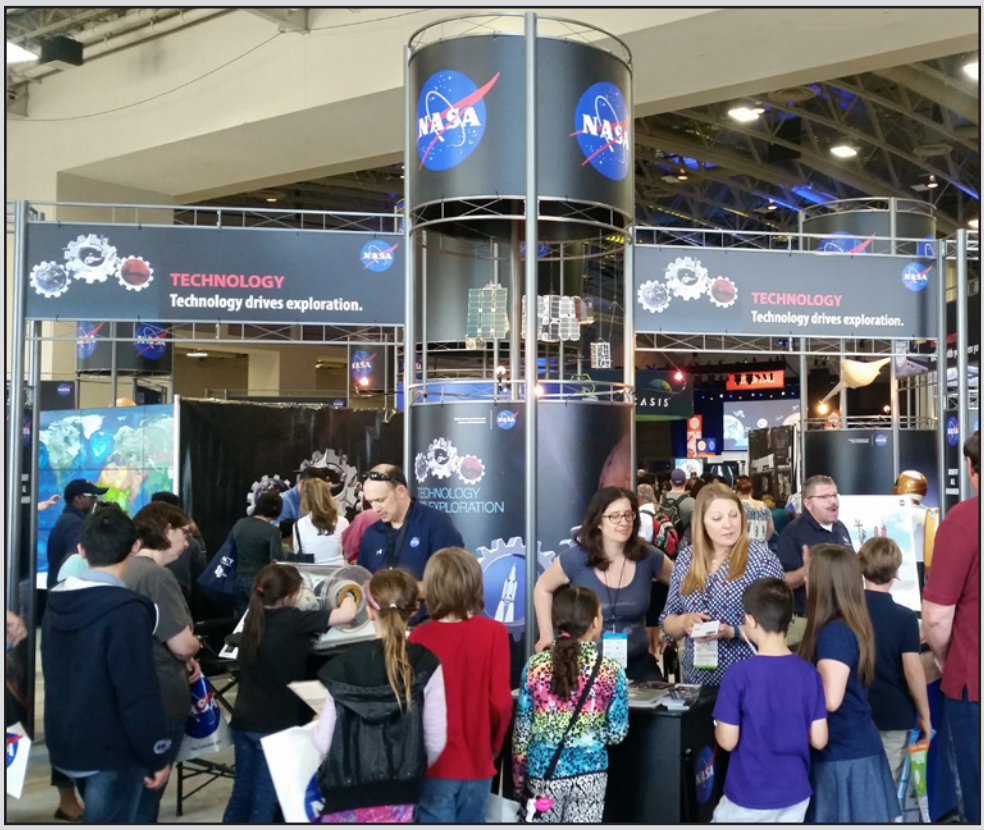
http://www.nasa.gov/mission_pages/tdm/main

Ball Aerospace Hosts Green Propellant Infusion Mission Media Day

Chris McLean, in left photo, principal investigator for NASA's Green Propellant Infusion Mission at Ball Aerospace & Technologies Corp. of Boulder, Colorado, and Steve Jurczyk, NASA associate administrator for the Space Technology Mission Directorate in Washington, were among GPIM team members who hosted a media day event in March to show off the promising Technology Demonstration Mission project. Members of the media, in right photo, also toured clean room facilities at Ball where the GPIM satellite is being stored prior to its scheduled flight test in early 2017, and talked with Julie Van Kleeck, vice president of project partner Aerojet Rocketdyne of Redmond, Washington; Ball Aerospace President Rob Strain; and U.S. Rep. Ed Perlmutter of Colorado's 7th Congressional District. (Images: NASA EDGE)

NASA Talks TDM at Science & Engineering Festival

NASA scientists and engineers talk all things space exploration with visitors at the annual Science and Engineering Festival in April at the Walter E. Washington Convention Center in the nation's capital. An estimated 365,000 visitors of all ages took part in the three-day festival, during which they took virtual reality walks on other planets, snapped selfies in a spacesuit, talked live with astronaut Jeff Williams aboard the International Space Station and learned all about NASA's Technology Demonstration Missions and other critical NASA technology efforts to boost future space missions and impact exploration of the solar system. The Space Technology Mission Directorate and TDM were on hand to show off the agency's new "Technology Drives Exploration" Google Cardboard app, technology photo kiosk and more. NASA partnered for the event with the Center for Advancement of Science in Space, or CASIS. (Image: NASA/Marshall/Carla Rosenberg)



Bill Nye the… GPIM Guy?

At the 32nd annual National Space Symposium, held in April in Colorado Springs, Colorado, science educator and TV personality Bill Nye, second from right, visits NASA's Journey to Mars exhibit – including key Technology Demonstration Mission projects crucial to future missions to the Red Planet and other NASA endeavors in space. Steve Jurczyk, third from right, NASA associate administrator for the Space Technology Mission Directorate in Washington, and Keyke Reed, left, TDM communications strategist in the TDM Program Office at NASA's Marshall Space Flight Center, showed Nye a scale model of the Green Propellant Infusion Mission payload, and shared information about that upcoming flight mission and other TDM projects forging new technology inroads for the benefit of NASA and the nation. The National Space Symposium is a leading global civil, military, industry and emergency space conference that typically draws some 9,000 participants from government agencies, non-profit organizations and commercial companies around the world. (Image: NASA/TDM/Keyke Reed)

GPIM, eCryo Projects Showcased in Latest NASA EDGE Report

NASA EDGE, the agency's informative, engaging video podcast series, has debuted its new "Scalable Technologies" episode, which showcases the Green Propellant Infusion Mission and Evolvable Cryogenics projects. NASA EDGE visits with Chris McLean, in top photo, Ball Aerospace principal investigator for GPIM, and Monica Guzik, in bottom photo, deputy product lead engineer for eCryo's integrated vehicle fluids task at NASA's Glenn Research Center. In the new episode, NASA EDGE hosts interview a number of eCryo and GPIM researchers at Glenn; at Plum Brook Station test facilities in Sandusky, Ohio, where cryogenic propellant storage and transfer technologies are being studied; and at GPIM project offices at Ball Aerospace in Boulder, Colorado. (Images: NASA EDGE)

Bridge Builder: GPIM's Susanne Plaisted Helps NASA Look Toward a Greener Future

Ball Aerospace systems engineer, Susanne Plaisted. (Image: Ball Aerospace)

Editor's Note: *TDM Bridge Builders are team members at NASA centers and partner organizations who are helping bridge the gap, bringing one of our cutting-edge technologies to flight readiness. Got a suggestion for a TDM teammate worthy of the spotlight? Email richard.l.smith@nasa.gov.*

Susanne Plaisted is a systems engineer at Ball Aerospace, the prime contractor for NASA's Green Propellant Infusion Mission. The GPIM project will demonstrate the practical capabilities of a hydroxyl ammonium nitrate-based propellant blend, known as AF-M315E, developed by the U.S. Air Force Research Laboratory. Ball's GPIM team also includes Aerojet Rocketdyne; the Air Force Space and Missile Systems Center; and NASA's Glenn Research Center, Goddard Space Flight Center and Kennedy Space Center.

In January, the GPIM spacecraft passed a major flight-readiness milestone marking the successful completion of functional and environmental testing of its systems and software. It is on track for launch in early 2017. The spacecraft – built on a Ball Configurable Platform 100 small satellite platform or "bus" – has been placed in storage as the team focuses on the propellant's handling and loading campaign.

Plaisted joined the GPIM team while she was still finishing her engineering degree at the University of Texas at Austin. She spoke recently with *The Bridge* about her experience as a young engineer and her hopes for the future of GPIM.

When did you join Ball? How long have you been involved in aerospace work?

I first came to Ball as an intern in the summer of 2013. I loved it and decided to return after I finished my degree. I've been a full-time employee since January 2014. Before coming to Ball, I also interned for United Airlines in aircraft interior engineering – an entirely different side of the aerospace industry.

I also got the great opportunity to work on various projects as a participant in Women In Aerospace for Leadership and Development, a student-run organization at the University of Texas. My two favorite WIALD projects were a payload flying on a sounding rocket to test commercial, off-the-shelf inertial measurement units, or IMUs, and a high-altitude balloon project called "BalloonSat" which flew multiple WIALD-developed payloads.

The IMU payload was the first time that something I worked on launched successfully into space. The feeling was amazing – there's nothing like it! The BalloonSat project was incredible because we managed every aspect of the development, including payloads, tracking systems and the balloon deployment itself. That launch was also exciting because an increase in winds caused us to solve problems in real time, creating some hectic balloon-saving techniques right on the tarmac. The chase as it landed was also exciting as we followed our live telemetry many miles across Texas until the balloon was recovered.

I love getting lost in a problem and exploring to find and create solutions. I really enjoy anomaly resolution because you have to be sure both personnel and hardware involved are safe, address the problem, search for a root cause and then make a decision for further action.

I think it's always easy to see how things will go right, but it's the moment that things don't go as planned that you truly get to use your knowledge. I've found these tend to be the best moments in which to learn from my more experienced coworkers.

What are your responsibilities on the Green Propellant Infusion Mission? What else do you do at Ball?

Originally I began on GPIM as a systems engineering intern. I focused mainly on the requirements verification planning prior to the spacecraft's Preliminary Design Review. I also worked on the Space Experiments Review Board's payload accommodation study.

Since returning to Ball as a full-time employee, I have worked as test engineer for GPIM. I was initially responsible for writing and modifying heritage procedures to be used in integration and testing of Ball's spacecraft bus. I then ran those procedures and worked on a team to take the spacecraft through its actual integration and testing. Now that it is in storage, I am eagerly awaiting next year, when I will get to be part of the GPIM launch team.

I am presently transitioning to support systems engineering for CloudSat operations and working toward becoming the back-up mission operations manager. Ball designed and built the CloudSat spacecraft bus. It carries a Cloud Profiling Radar payload, built by NASA's Jet Propulsion Laboratory, to create a vertical profile of cloud structure. This allows scientists worldwide to create a 3-D model to use for global climate and weather predictions.

What do you hope most to accomplish on GPIM? What's the payoff you're most excited to see?

I'm incredibly excited to see us investing in testing a new propellant and thruster on orbit! I can't remember when there has been so much invest-

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ment in new propellant technologies. It'll be great to see how GPIM affects future spacecraft once AF-M315E has been successfully tested. I hope this project paves the way for both future investments in technology and also in further and greater missions.

One of the most exciting opportunities that I see is an application for future Mars missions due to the thermal properties of AF-M315E. It greatly opens up the possibilities for *in-situ* resource use on the Martian surface.

How will GPIM–and your contributions in particular–impact Ball's and NASA's goals for the future?

By contributing to the test program where the GPIM spacecraft and payloads were comprehensively tested, I believe I've given the vehicle the best chance at successfully completing its mission, both by ensuring its performance meets the specifications and by helping the project team to fully understand the expected behavior of the vehicle on orbit. It's exciting to think that my work will be "heritage" for any future technology demonstrations on orbit that use this same Ball spacecraft bus.

On a larger scale, I hope that–by being a part of the team that got GPIM quickly, efficiently and safely through integration and testing–I've helped ensure that Ball and the TDM program will continue to build and execute future small satellite technology demonstration missions.

Plaisted at work on the GPIM spacecraft at Ball facilities in Boulder, Colorado. (Image: Ball Aerospace)

National Aeronautics and Space Administration

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