Cameras Improve Navigation for Pilots, Drivers

NASA Technology

After 10 months of traveling through deep space to Mars, the Phoenix Lander finally approached its destination. The last 7 minutes of the spacecraft's 423 million-mile-journey—the entry, descent, and landing (EDL) phase—were the most critical and also the most difficult. In the history of Mars landing missions, only 5 of 13 attempts have succeeded. It would have been tragic for Phoenix to go so far yet fail to arrive safely.

Landing on the Red Planet is extremely challenging. Tucked inside its aeroshell, Phoenix entered the atmosphere of Mars at a speed of 12,750 miles per hour. After decelerating using atmospheric drag and a parachute, Phoenix discarded its aeroshell in preparation for touchdown in a region characterized only by orbital reconnaissance data. Lacking real-time terrain mapping and hazard-avoidance capabilities, Phoenix faced the potential for serious damage or tip over from landing on a rock or other surface hazard during the final seconds of the mission.

To ensure the future success and reliability of such crucial landing missions, NASA is investigating a variety of terrain-sensing technologies, including cameras capable of producing real-time, 3D images of planetary terrain under any lighting conditions to reveal hazards and to enable accurate navigation to a safe landing location.

An artist's concept depicts NASA's Phoenix Mars Lander just moments before landing on Mars. NASA is investigating camera technologies to produce 3D images of planetary terrain in real time to reveal landing hazards and to enable accurate navigation for spacecraft like Phoenix.

Partnership

Advanced Scientific Concepts Inc. (ASC), of Santa Barbara, California, received a Small Business Innovation Research (SBIR) award from the Jet Propulsion Laboratory (JPL) in 2006 to assess the suitability of ASC's 3D flash light detection and ranging (LIDAR) video camera for EDL applications. With the SBIR funding, ASC tested the technology on simulated Martian landscape at the JPL Mars Yard.

"We want the ability to be able to make a real-time map of the hazards as we are landing so we can avoid them. That is what LIDAR is ideally suited for," says Gary Spiers, supervisor of the Active Optical Sensing Group at JPL.

To develop an integrated landing system capable of detecting and avoiding surface hazards and guiding a crewed or robotic lander to a safe and accurate touchdown, NASA chartered the Automated Landing Hazard Avoidance Technology (ALHAT) Project in 2006. The ALHAT team, combining technical expertise from the Johnson Space Center, Langley Research Center, Draper Laboratory, and JPL, identified flash LIDAR technology as a highly promising approach for real-time terrain mapping and hazard detection. ASC subsequently received several SBIR awards and a NASA Research Announcement contract to continue the development and refinement of 3D flash LIDAR technologies. Over the past few years, several combinations of ASC flash LIDAR sensors and related lasers and optical components have been evaluated by NASA personnel in the lab, in the field, and in airborne tests.

"The primary reason NASA was interested in the technology was for safe landings. The second priority was for rendezvous and docking at the International Space Station," says Farzin Amzajerdian, a senior scientist at Langley leading the LIDAR sensor development effort for ALHAT.

At Johnson, the Commercial Crew and Cargo Program Office (C3PO) invests resources to stimulate the private sector to develop and demonstrate space transportation capabilities. Under the Commercial Orbital Transportation Services project of this office, Hawthorne, California-based SpaceX is developing its Dragon spacecraft to deliver cargo and supplies to the International Space Station (ISS). Because SpaceX intends to use ASC's technology to assist with docking at the ISS, the flash LIDAR device flew on both STS-127 and STS-133 for demonstration and evaluation.

"The technology is used to determine how you are posed in relation to a target, how far away you are, and how fast you are moving in relation to it," says Warren P. Ruemmele, assistant project executive for C3PO. "If earlier investments hadn't been made and successful, it wouldn't be a candidate for what we are trying to do."

Benefits

ASC's flash LIDAR sensors use a short pulse of radiation from a near-infrared laser to illuminate a scene in front of the camera lens. Each pixel in the camera detector array measures the round trip time for the photons, which is then converted into an accurate range measurement. Each pulse of the flash LIDAR produces a 3D image consisting of thousands or tens of thousands of points acquired essentially simultaneously, which effectively eliminates motion-induced distortions.

A graphical user interface on a computer displays the data in the form of a color-coded range (distance) map. Current ASC flash LIDAR cameras are capable of acquiring 3D images at rates of up to 30 frames per second, which can be viewed as a video and processed for identifying various scene features. In practice, a data processor could autonomously analyze the surrounding environment and execute vehicle maneuvers.

Two versions of ASC's 3D flash LIDAR camera are currently available: the DragonEye Space Camera (named after the Dragon spacecraft), and a terrestrial version called TigerEye. Both products incorporate improvements that resulted from working with NASA to make the camera ready for space—including its compact size, low power, light weight, and enhanced performance and sensitivity.

"After we brought the technology to NASA, they helped us develop it for space applications. That refined it for other applications," says Dr. Roger Stettner, founder and president of ASC.

A number of large- and medium-sized aerospace organizations, including SpaceX, Ball Aerospace, and Northrop Grumman, have purchased flash LIDAR cameras from ASC. By 2010, ASC had sold about 100 cameras—not only for potential space use, but for use on Earth as well. 3D flash LIDAR cameras can assist almost any manned or unmanned vehicle with collision avoidance, navigation, or object tracking—through brownout (helicopter-landing-generated dust clouds) conditions, tree leaves, smoke, fog, darkness, or under water. It could also be used for surveillance around the perimeter of a facility or at a border.

Advanced Scientific Concepts Inc. refined this 3D flash light detection and ranging video camera through SBIR work with NASA. The space version of the camera can assist vehicles docking at the International Space Station, and the terrestrial version can assist with navigation and collision avoidance here on Earth.

"The cameras can be the basis for a solution that would give pilots situational awareness, visibility, and the ability to map the terrain while coming in for a landing—in much the same way you would expect of a spacecraft landing on the Moon or Mars," says Dr. Stettner.

One particularly useful application is in cars and trucks. When mounted on an automobile, the technology can show a driver how close or far away things are to assist in avoiding collisions. A monitor on the car would distinguish how far away others cars, bicyclists, or pedestrians are, as well as how fast they are moving. Objects that are closer might appear red in the image while objects that are far away might appear green. According to ASC, the cameras could come standard on high-end automobiles in just 6 to 8 years.

In the meantime, NASA continues to fund flash LIDAR technology development efforts through SBIRs and projects such as ALHAT to progress toward a more robust and flight-like sensor configuration with a larger detector array, greater sensitivity, finer range resolution, lower range measurement noise, and flight-qualified electronics and detectors. The objective is an optimal combination of laser power, operational range, and sensor mass and performance for NASA missions.

The way Thomas Laux, vice president of business development at ASC, sees it, "There is a future within NASA—and certainly outside of NASA—for this technology." ❖

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