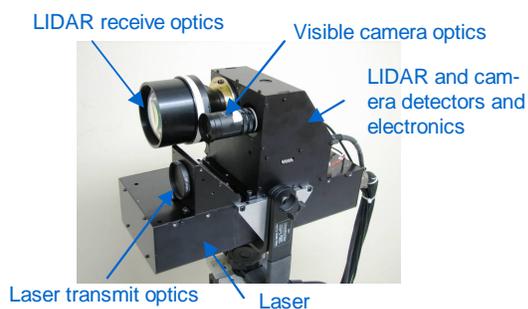


APPLICATIONS AND FIELD TESTING OF A FLASH LIDAR SYSTEM FOR FUTURE PLANETARY MISSIONS. J.D. Weinberg (jweinber@ball.com), R. Dissly, D. Nicks, K.L. Miller. Ball Aerospace & Technologies Corp., PO Box 1062, Boulder, CO 80306-1062.

Introduction: Ball Aerospace and Technologies Corp has developed and field tested a versatile Flash LIDAR instrument which can provide real-time (30 Hz) imaging for a wide variety of planetary science and exploration mission applications. The instrument has an overall Technology Readiness Level of 5 (prototype validation in a relevant environment), built with subassemblies which have even greater maturity, including flight heritage. Ball is currently developing flash LIDAR for a 2010 flight (discussed below).

This paper highlights key features of the flash LIDAR instrument, discusses direct applications of the system for planetary science investigations, and describes instrument maturity, including ongoing efforts and results from recent field testing.

Flash LIDAR Features: Flash LIDAR systems are analogous to a camera with a flashbulb (flood illumination), but with the flash being provided by laser illumination and the use of a detector with a clock to determine the time it takes for the flash to depart, reflect off of the target, and return. By measuring the time of flight of the reflected laser pulse, the sensor can determine a range measurement along with intensity for each pixel in the image. This information set over the range of all detector pixels is referred to as a 3D LIDAR image or point cloud.



Ball's 5th generation flash LIDAR prototype

The entire scene within the sensor's field of view (FOV) is imaged with a single flash of the laser. This directly produces an image that has each pixel correlated in time, which makes the sensor insensitive to relative motion between the spacecraft and target subject and eliminates the need for complex processing algorithms to account for relative motion or laser scan time over the FOV. Our latest prototype design produces 256x256 pixel 3D images, with <5cm ranging accuracy, in real time at rates up to 30 Hz.

Flash LIDAR is inherently insensitive to ambient and stray light. Because the system captures a new complete image with each flash, glint and clutter outside of the expected range to the target may be filtered and discarded. This capability makes data processing extremely efficient and reliable since range, bearing, and pose algorithms do not have to deal with interpreting data from glint and clutter. Rapid frame rates, waveband filtering, and time gating on the return signal increase glint tolerance even further.

Planetary Mission Applications:

In-Space Topographic Mapping: The flash LIDAR may be used as a topographic mapper from orbit about a planetary body or in a following orbit with a small body such as a comet or asteroid. It provides real-time 3D surface information under any lighting conditions and can operate while the spacecraft is in motion without compromising data integrity.

Ranging: When operating in the 3 degree of freedom mode, long distance targeting and ranging may be accomplished as far away as several hundred kilometers (depends upon laser power and target albedo).

Surface Operations: A fast imaging rate (30 Hz) allows detection of hazards during real-time operations. High resolution maps of terrain and rock surfaces may also be obtained.

Autonomous Rendezvous and Docking: The LIDAR system may be used as a docking sensor for interfacing with a carrier spacecraft or for a rendezvous with a non-cooperative target.

Descent and Landing: The flash LIDAR can play a critical navigation role during two key phases of descent and landing. For initial entry, the LIDAR is used for altimetry and velocimetry. Terrain relative navigation can also be performed, even under low light conditions, operating in a narrow FOV mode. During terminal decent, the LIDAR beam is diverged to illuminate the desired field of regard, for hazard detection prior to landing.

Heritage & Low Risk: The laser used in our current flash LIDAR design is derived from our Cloud-Aerosol LIDAR and Infrared Pathfinder Satellite Observations (CALIPSO) instrument. CALIPSO was launched in April 2006 and has been in continuous operation since, delivering critical new data for climate change research with over 1.3 billion laser pulses and counting.

Ball Aerospace is in full-scale development of the relative navigation flash LIDAR for the NASA Crew Exploration Vehicle, Orion, with an initial spaceflight demonstration planned for early 2010.

Ball is also developing a 10x zoom optic for NASA under the ALHAT program. The ALHAT program supports Constellation landing missions.

Field Tests: Ball Aerospace has worked for more than four years to mature the flash LIDAR technology. Extensive and on-going investments have produced five generations of flash LIDAR prototypes. These systems have been successfully tested in the laboratory, with local field experiments, at several NASA centers and with in-flight airplane and helicopter field tests. A synopsis of these tests include:

Topographic Mapping (Twin Otter Flight): Made topographic maps of the surface, imaged and detected hazards, validated spatial resolution and ranging (altimetry) capabilities.

Long Distance Ranging (Ball): Radiometric and ranging performance were validated with in-atmosphere tests from the Ball rooftop laboratory to targets 2.5 km (University of Colorado) and 5.5 km (National Center for Atmospheric Research) away.

Surface Navigation (NASA Ames): Characterized indoor hazards as well as outside longer range imaging (navigation). Performed Mars-scape topographic mapping.

Hazard Detection for Landing (NASA Langley Research Center & Marshall Space Flight Center): Used a Langley developed facility to test the hazard detection capability of the sensors. To date, Ball's flash LIDAR is the only sensor that has been tested at this facility. Algorithms for target and hazard recognition were also tested at Marshall facilities.

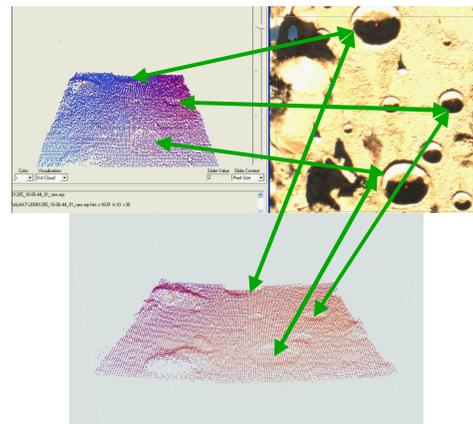
Autonomous Rendezvous and Docking (Marshall Space Flight Center): Two proximity operations/docking tests were performed. Ball's LIDAR is the only system which provides real-time data and pose estimation (trajectory, attitude and attitude rate). Tests were performed under a variety of possible lighting conditions.

Helicopter Flight Test: Ball Aerospace, in conjunction with Northrup Grumman Integration Systems (NGIS), has recently completed a helicopter field test of the flash LIDAR. The Ball flash LIDAR and a [visible light] video camera were mounted on the bottom of a Bell 206 helicopter.

Twenty-six separate flight profiles with a total of 74 passes were accomplished during December, 2008. Each pass included real-time LIDAR data collection as well as camera video and inertial navigation data collection.



Results: The data yielded excellent visible and LIDAR 3D imagery, including calibrated slopes and surface features of various shapes and sizes. Data were taken from various altitudes from 10 to 1400 ft. Data were also taken from different approach angles and speeds.



LIDAR and visible image frames, taken during descent from 500 to 300 ft at a rate of 300 ft/min.