Large format time-of-flight focal plane detector development

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Abstract

This paper reviews the progress of Advanced Scientific Concepts, Inc (ASC) large format flash ladar 3-D imaging systems for longer-range applications. Single-laser-pulse images are taken from a manned flight test at 1000 - 2000 ft demonstrating not only the 3-D mapping potential of the system but also its use in object identification. Gated images on the ground exemplify vehicle identification applications. Use of signal amplitude information in enhancing the 3-D image is also illustrated.

Keywords: Flash Ladar, 3-D Imaging, 3-D Focal Plane Array

1. Introduction

3-D ladar (or lidar) imaging, using a single laser pulse for each frame of data – flash ladar - requires 3-D focal plane arrays (FPA) incorporating rows and columns of pixels, similar to 2-D FPAs that are common in digital cameras today. Flash ladar cameras operate and appear very much like these conventional 2-D digital cameras with smart pixels substituted for simple signal integrators; each pixel can accurately and independently count time to the target. A broad area, short, laser pulse replaces the flash of the 2-D camera. The out-going laser pulse is reflected from a target and focused on the 3-D focal plane where the independent pixel clocks are stopped. The time between the launching of the pulse and the return is proportional to the range via the velocity of light. Development of 3-D focal planes have taken a relatively long time. Reference 1 shows the first flash ladar 3-D image taken with an analog-based design (Reference 2). Reference 3 illustrates the first 3-D flash images taken with an alternate FPA design incorporating digital processing.

Flash ladar 3-D cameras offer advantages of small size, low weight, high speed and low cost. These advantages arise primarily because each laser pulse generates an entire frame of data, rather than one-pixel for each laser pulse, and entire frames are registered, not each pixel individually. Reference 3 exemplified the feasibility of 3-D flash ladar concept as well as illustrating the compact system size. The focus of this paper is on demonstrating the practical capability of these larger format 3-D imaging systems in object identification and topographical mapping. These particular applications are important to the military for reconnaissance, operational planning and targeting. Further applications deriving from the small size and low weight include unmanned ground vehicle and unmanned air vehicle navigation and reconnaissance. 3-D sensor output can be combined with the 2-D output from other sensors of various wavelengths to enhance object identification. These combined sensors can be incorporated in gimbals, scanning systems or static platforms. Further savings in weight and volume can be achieved by designing common aperture 3-D/2-D systems.

This paper is organized as follows: First the components of a 3-D imaging flash ladar system are described along with the experimental configuration. Then the data is presented with associated commentary. Finally conclusions are drawn.

2. Experimental Configurations

3.

The sensor board (Figure 1 RHS) in the ASC handheld 3-D imaging flash ladar camera (Figure 1 LHS) depicted in Figure 1 below was used in the generation of all the images in this paper. The focal plane consists of an ASC

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designed 128 x 128 ROIC indium bump bonded to InGaAs PIN diodes. The PIN diode arrays were custom fabricated by Sensors Unlimited Incorporated for the ASC's FPA size, pitch and polarity. Various lasers of pulse energy from a few to 45 mJ, at a wavelength of 1.57 um were used to produce the images in this paper. All the optics and all mechanical housings were custom designed by ASC for the particular system. Figure 2 illustrates the flight configuration designed to validate critical features of a UAV-based mapping/reconnaissance system.

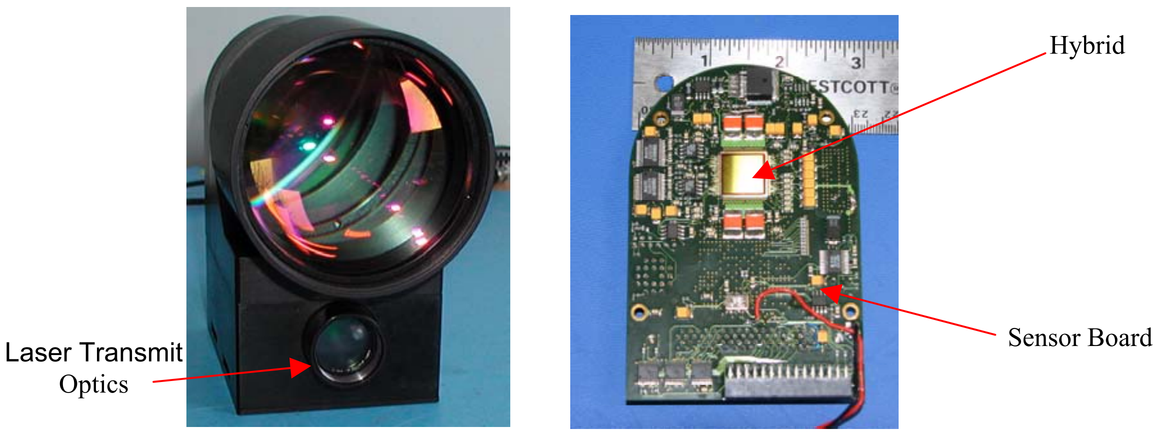

Figure 1. Handheld ASC 3-D Flash Ladar Camera Showing FPA and Associated Electronics as well as ASC Designed Optics. Right hand side (RHS) is the camera sensor board and the Left Hand Side (LHS) shows the laptop-operated camera

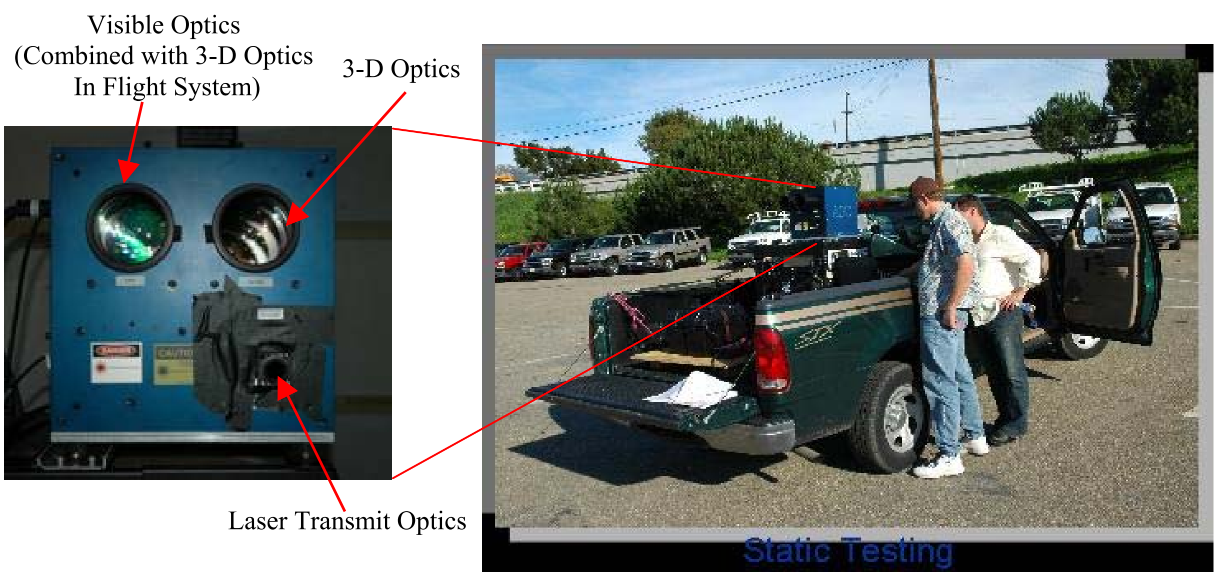

Figure 2. Flight Test System in Static Vehicle Test Configuration. The goal of this system development project is a UAV-based topographical mapping system with the capability of 350 km^2/hr, a volume less than 1 ft^3 and a total weight including GPS and INS less than 50 lbs.

4. Experimental Data

Figure 3 illustrates a single laser pulse 3-D raw-data image taken with the Figure 1 camera. The image is color coded for range. Range was determined using the ASC range algorithm. Shading resulted from amplitude processing of the data.

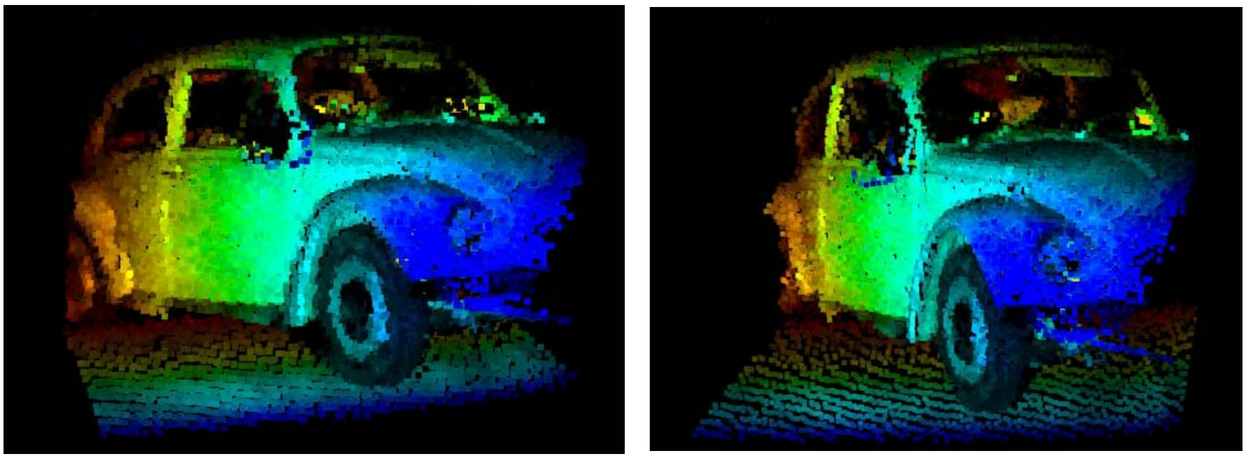

Figure 3. Two Orientations of the Same Single-Laser-Pulse 128 x 128 3-D image. Data was processed using the ASC range algorithm only and so is essentially a raw-data image. Color-coded for depth. Although a raw image, the vehicle type is clear.

The remaining single pulse 3-D flash ladar images shown in this paper were acquired with the Figure 2 system in a airplane flight test confituration. All are raw data. Figure 4 illustrates the power of 3-D imaging for aircraft identification. The speed-of-light frame acqusition reduces all moving objects to static images.

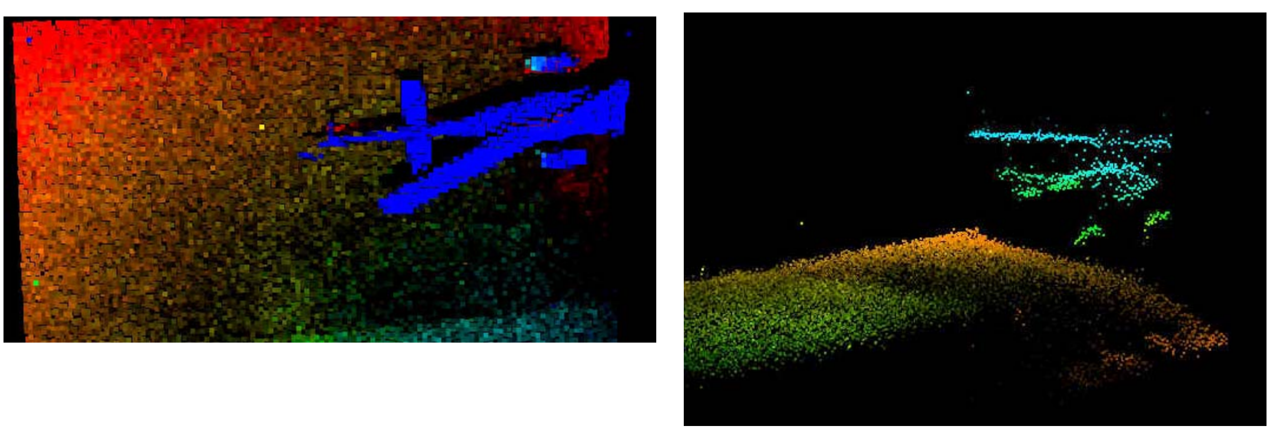

Figure 4. Two Orientations of the Same Helicopter 3-D Image at 1300 ft. Left hand side is down looking and right hand side is a front looking, rotated 3-D image. Note the shape of the rotor blade is captured by the speed-of -light system and that rotation of the 3-D image dramatically increases the capability for object recognition.

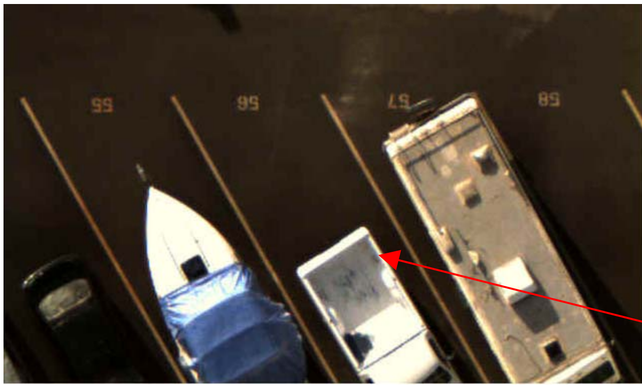

Figure 5. Two-Dimensional Visible Camera Image of Parking Lot

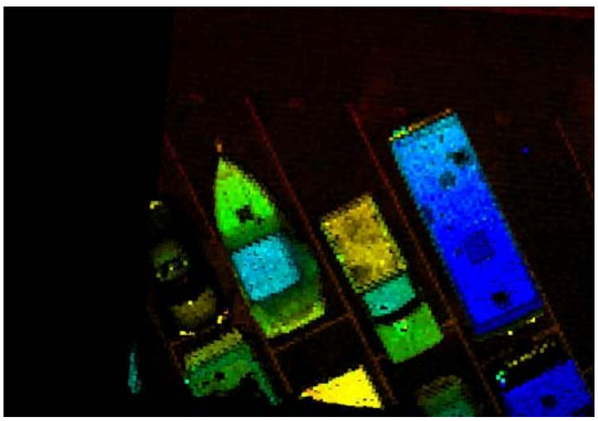

Figure 6. Parking Lot 3-D Image at 1000 ft. Color denotes range.

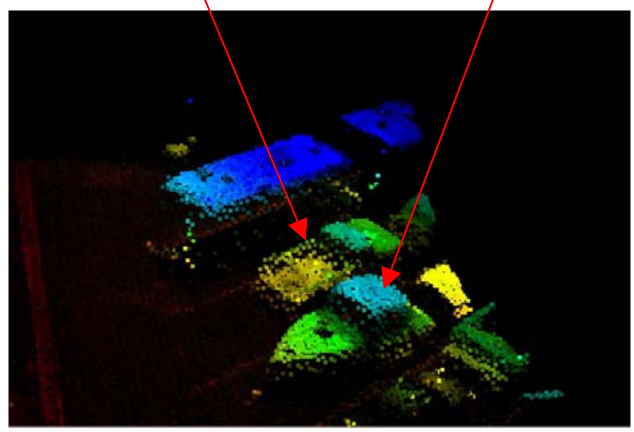

Figure 7. Rotated Figure 6 Image. Note depth of the truck bed and height of boat cover.

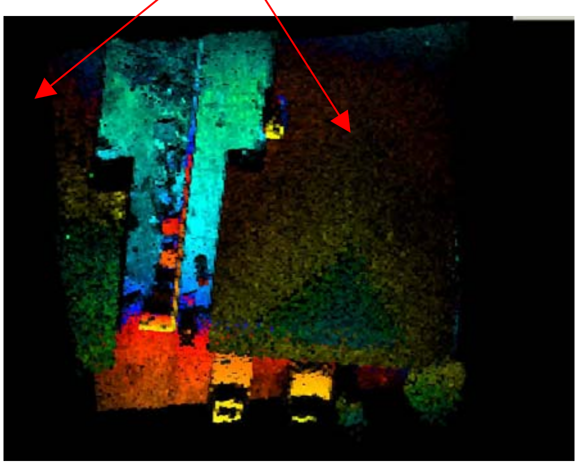

Figure 8. Down looking 3-D Image of Two Roofs. Color Denotes Range

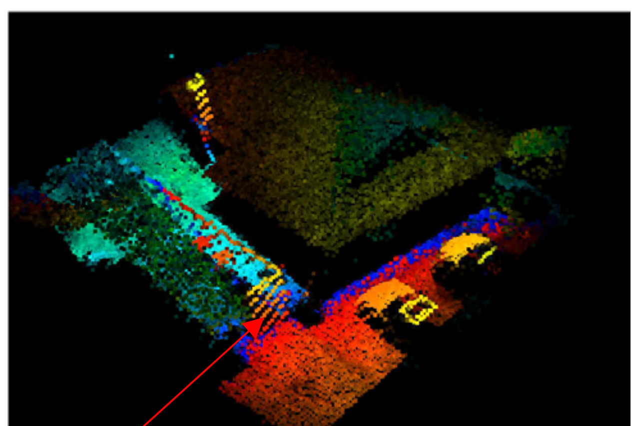

Figure 9. Rotated Figure 8 3-D Image. Shows presence of cyclone fence and automobile height.

Stitching frames of data together, such as those in Figure 8, utilizing a software tool such as described in Reference 4, would result in 3-D mapping system.

4. Conclusions

This paper presented 3-D flash ladar imaging results from ASC's newest imaging systems. These results clearly illustrate the object identification and 3-D mapping capability of the technology. The results as well as the camera size demonstrate the practicality of 3-D flash ladar technology.

5. Acknowledgements

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6. References

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