

National Aeronautics and Space Administration



DEVELOPMENT OF FLASH LIDAR SENSOR FOR PRECISION SAFE LANDING

Farzin Amzajerdian, Alexander Bulyshev, Paul F. Brewster , Aram Gragossian , Jacob M. Heppler , Frederick G. Wilson , Glenn D. Hines , Sean A. Laughter , and Daniel K. Litton

NASA Langley Research Center

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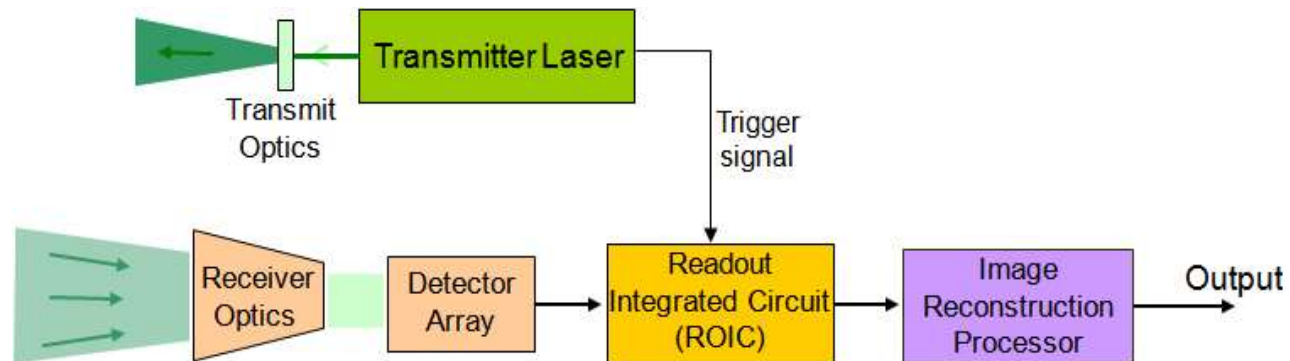
June 8th - 14th

Williamsburg, Virginia

3-D Imaging Flash Lidar Sensor



- **Flash lidar presents several advantages over scanning lidars for hazard detection and safe landing on planetary bodies**
 - Does not require vehicle motion correction
 - Generates organized 3-D pattern (does not need oversampling of the landing site)
 - Able to perform other functions critical for precision navigation



Flash Lidar Landing Operation Concept



Altimetry

30 km



20 km

Updating IMU
and reducing
position errors

A-TRN

5 km

Acquire low-resolution
3D terrain images to
identify known features



HDA

1 km

Acquire elevation
maps and select
landing location



0.5 km

HRN



Flash Lidar Descent and Landing Requirements



- Commercial linear-mode flash lidar camera has $128 \times 128 = 16.4\text{k}$ pixels
- Mapping $100 \text{ m} \times 100 \text{ m}$ area with 15 cm Ground Sample Distance (GSD) requires $\sim 0.5 \text{ M}$ pixels
- Developed a Super-Resolution algorithm to meet HDA requirements without the need for a mechanical gimbal or scanning mirror

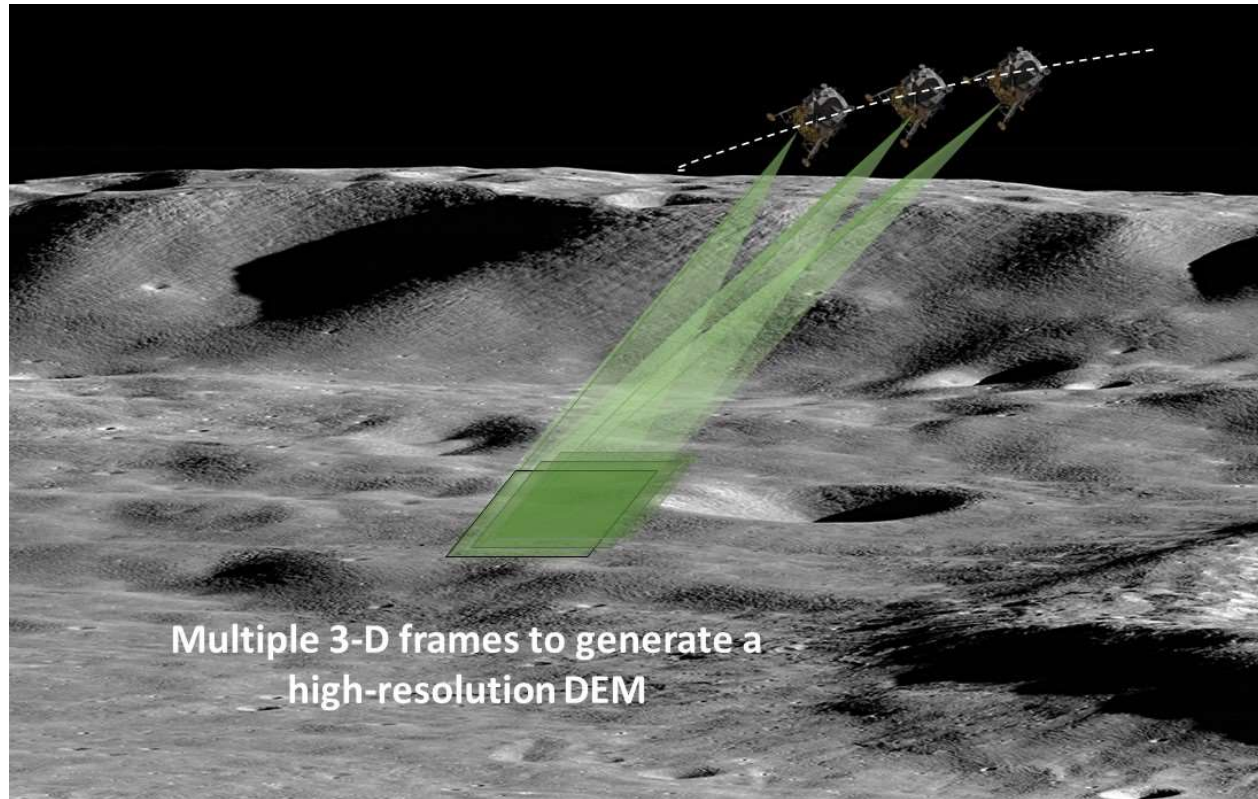
Flash lidar closed-loop demonstration onboard rocket-powered Morpheus vehicle (2014)



Flash Lidar Super-Resolution Algorithm



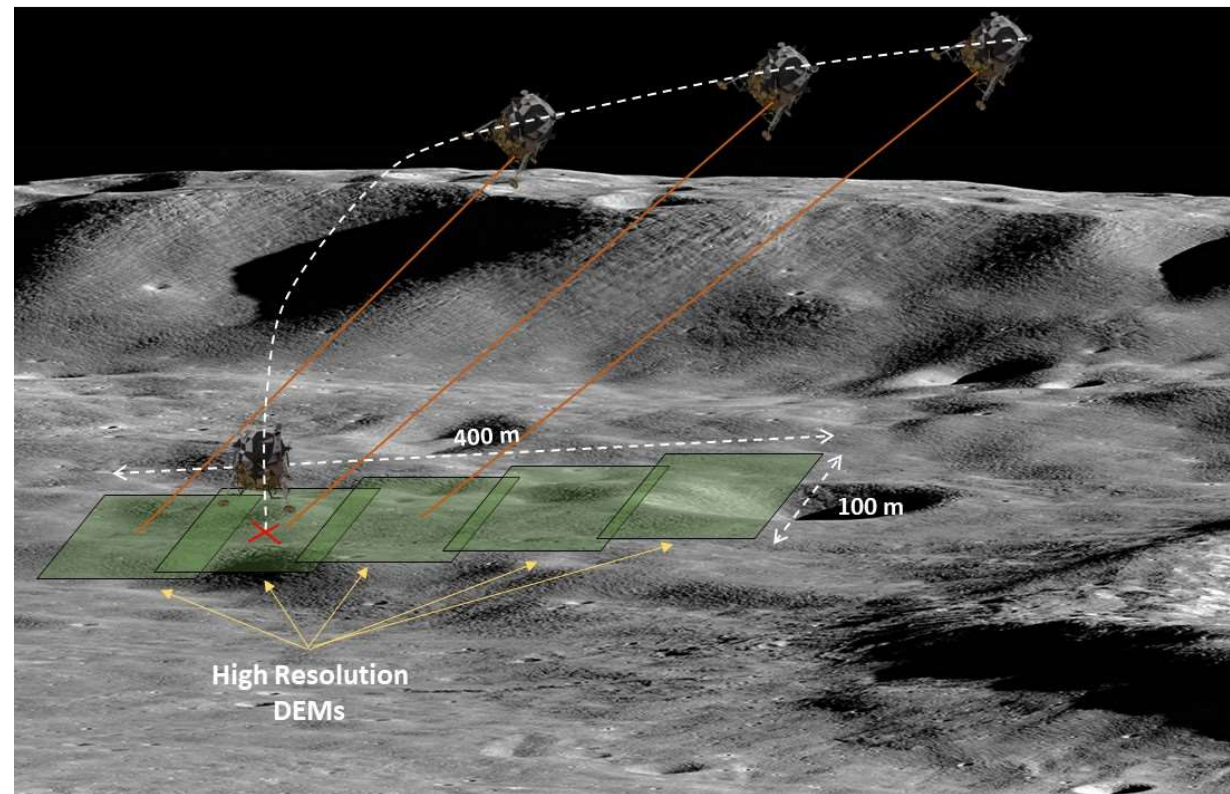
- Super-Resolution (SR) technique uses a set of consecutive frames, from slightly different positions and angles (resulting from platform motion), to generate a high-resolution DEM
- No external sensor data is required
- Generates high-res DEMs at 1 Hz rate using 20 frames



Flash Lidar Generates Multiple High-Resolution DEMs



- DEMs and Hazard Maps are generated every 1 second with 30 msec latency
- Can cover up to 100 m x 400 m area and identify safe landing locations in 5 seconds

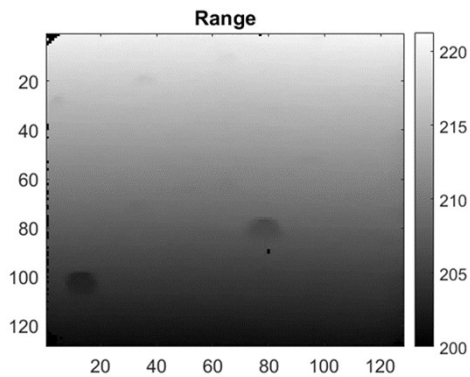


Helicopter Flight Test

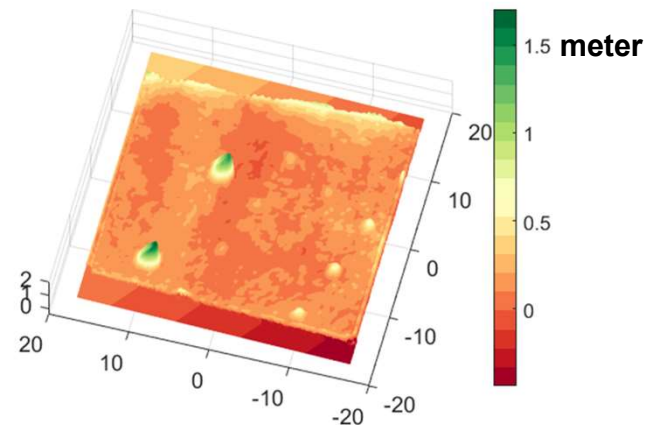


- 100% hazard detection from 250 m @ 45° look angle
 - Smallest hazard: 25 cm dia x 35 cm height

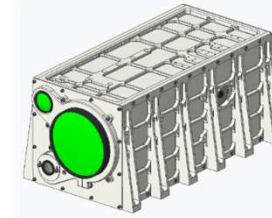
Single Frame



Real-time
Elevation Map



Breadboard
Flash Lidar

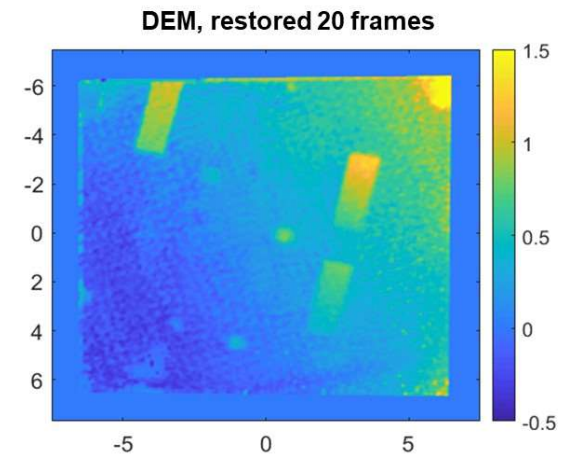
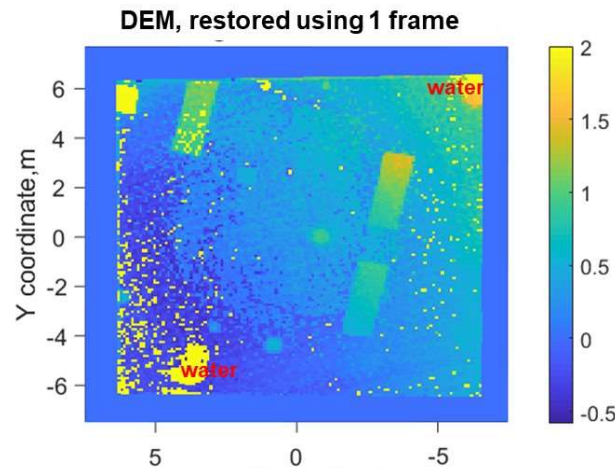
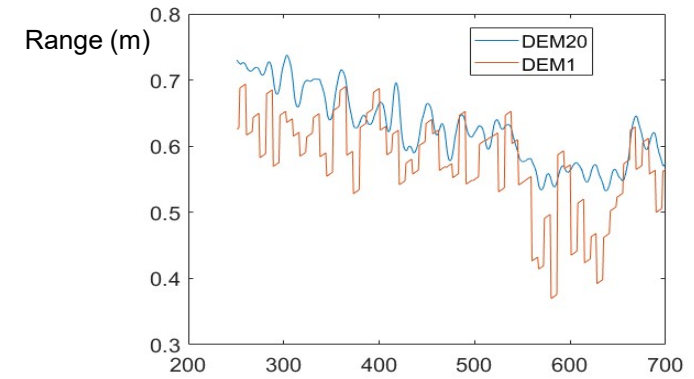


NASA LaRC Flash Lidar is the only active sensor technology that has successfully demonstrated hazard detection

Performance of Real-Time Super-Resolution Algorithm



- Generated DEMs at 1 Hz rate with ~ 30 msec latency
- Resolution enhancement by 25X (0.4M pixels)
- Range resolution enhancement by 2X (4 cm)
- Range noise reduction by > 2 X (3 cm)
- Effectively recovered dark pixels



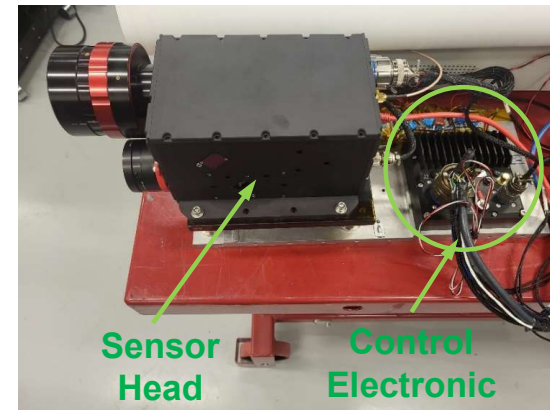
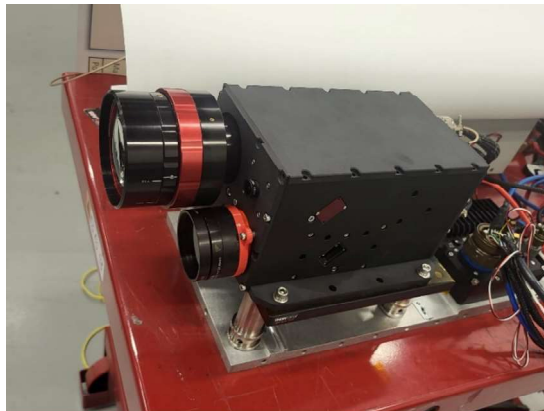
Multi-mode Flash Lidar (MFL)



Upgrades over breadboard

- Extend HDA operational range to > 1.0 km
- Update image enhancement algorithms
- Incorporate long range *Altimetry* and active *Terrain Relative Navigation* functions
- Compact design

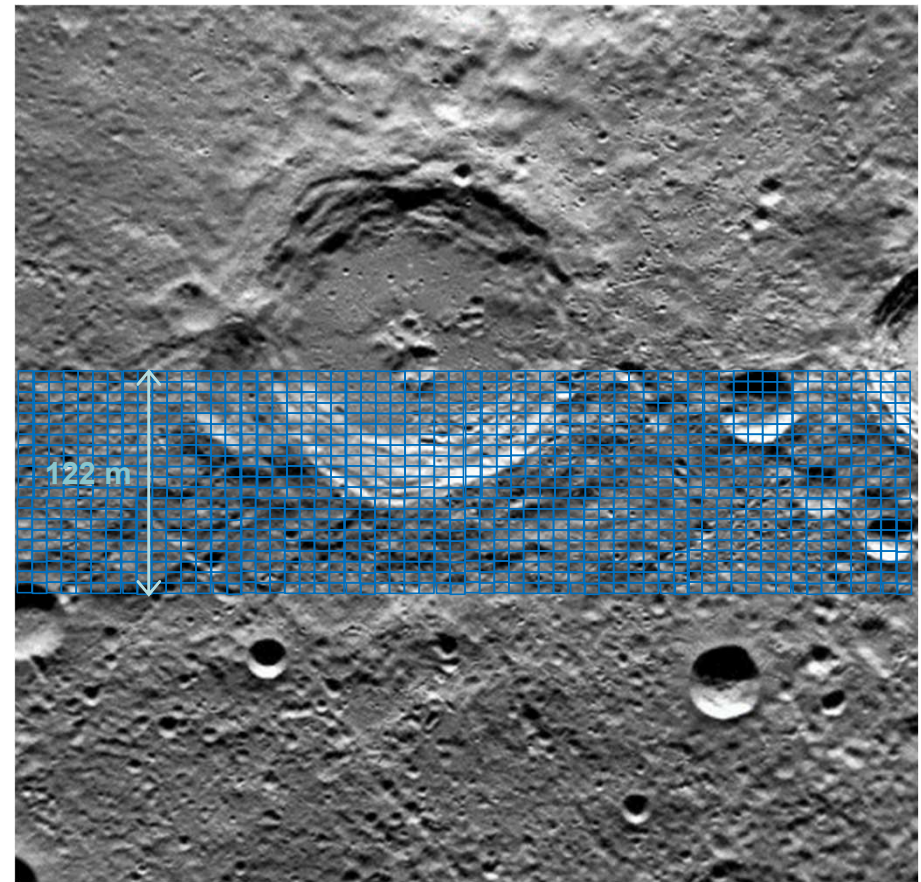
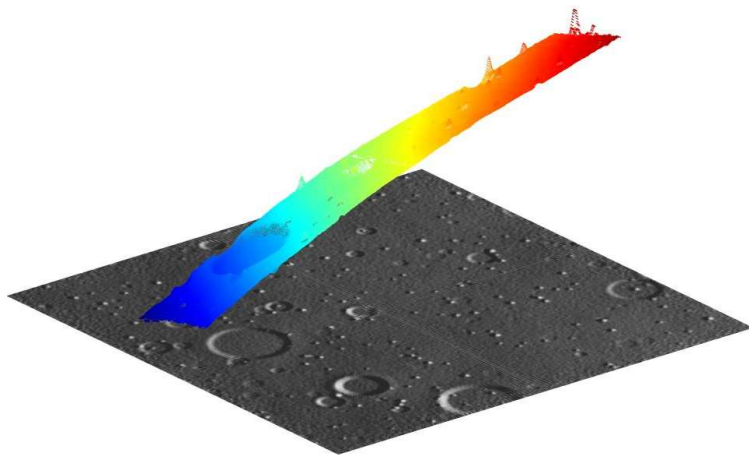
Dimensions	Sensor Head	11.8"x6.6"x4.7"
	Controller box	9.0"x9.0"x2.5"
Weight	Sensor Head	8.5 lb
	Controller box	5.5 lb
Power		55 W



MFL TRN Function



- Generates 122 m wide swath
- Sufficient overlap of image frames for applying SR algorithm
- 5 m resolution at 15 km matching LOLA elevation maps pixel size





Backup

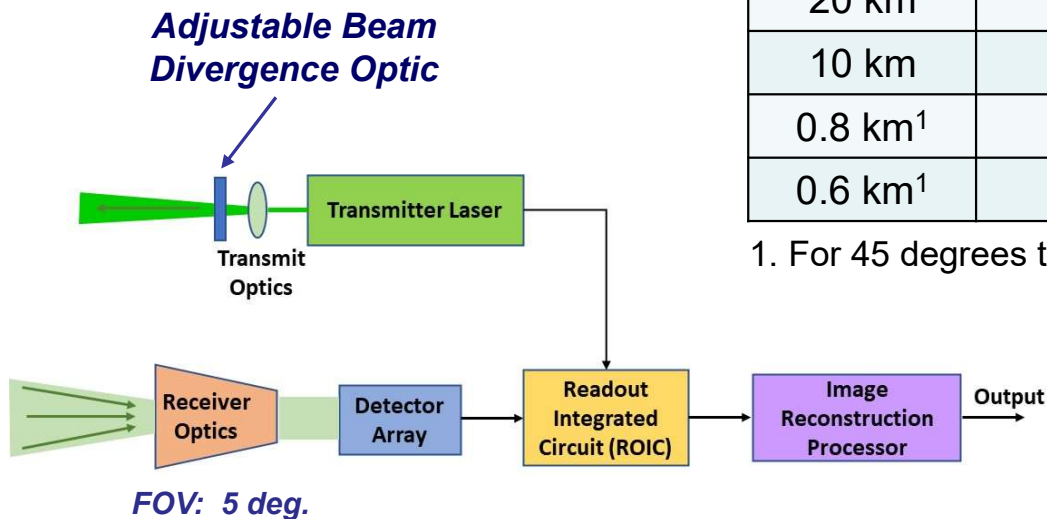
Flash Lidar Multifunctional Operation



- Laser beam divergence is reduced to extend operational range for altimetry and active TRN functions

Altitude	Function	Beam Divergence (deg.)	GSD (m)	No of Illuminated Pixels
30 km	Altimetry	0.2	20.1	5 X 5
20 km	TRN	0.35	13.6	9 X 9
10 km	TRN	0.7	6.8	18 X 18
0.8 km ¹	HDA	5.0	0.74	128 X 128
0.6 km ¹	HDA	5.0	0.58	128 X 128

1. For 45 degrees trajectory



Development and Testing of Flash Lidar with Real-Time Algorithms at NASA LaRC



Gantry Test



Flash Lidar



Drone Flight Test



Breadboard
Flash Lidar

