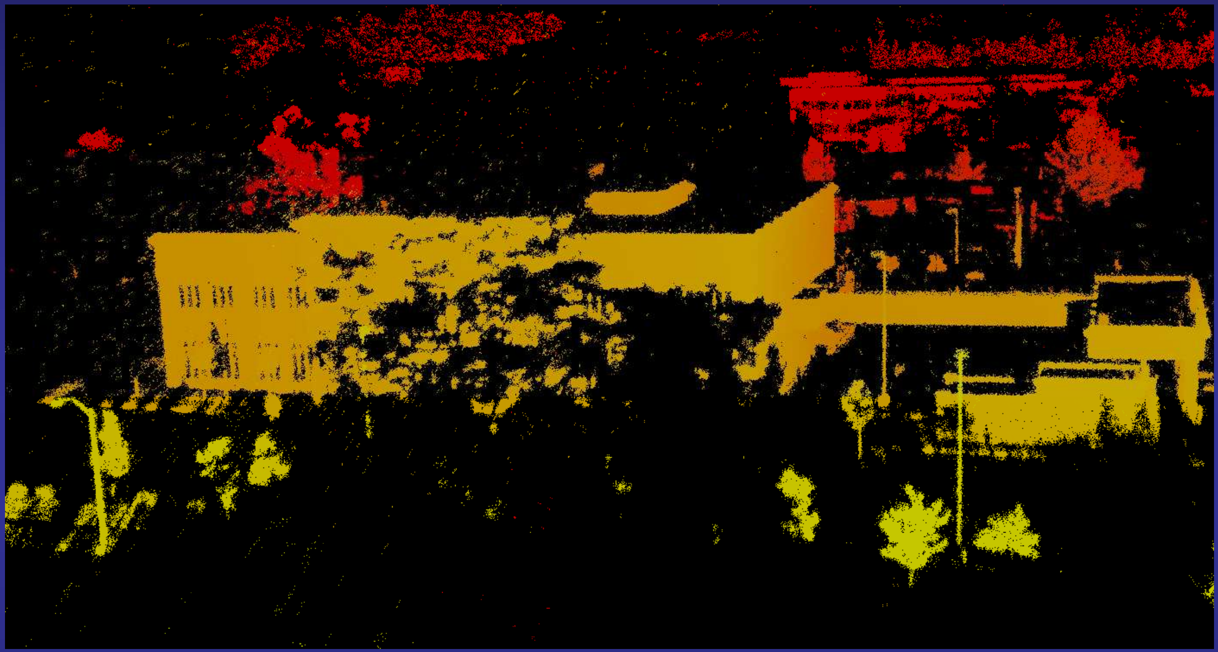
Photon-Counting 3D Imaging Lidars



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ILRS Workshop, Grasse, France
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Sigma Space 3-D Imaging Lidar Technology

- Transmitter is a low-energy (6 μJ), high rep-rate (to 20 kHz), frequency doubled (532 nm), passively Q-switched microchip laser with a 710 psec pulsewidth.

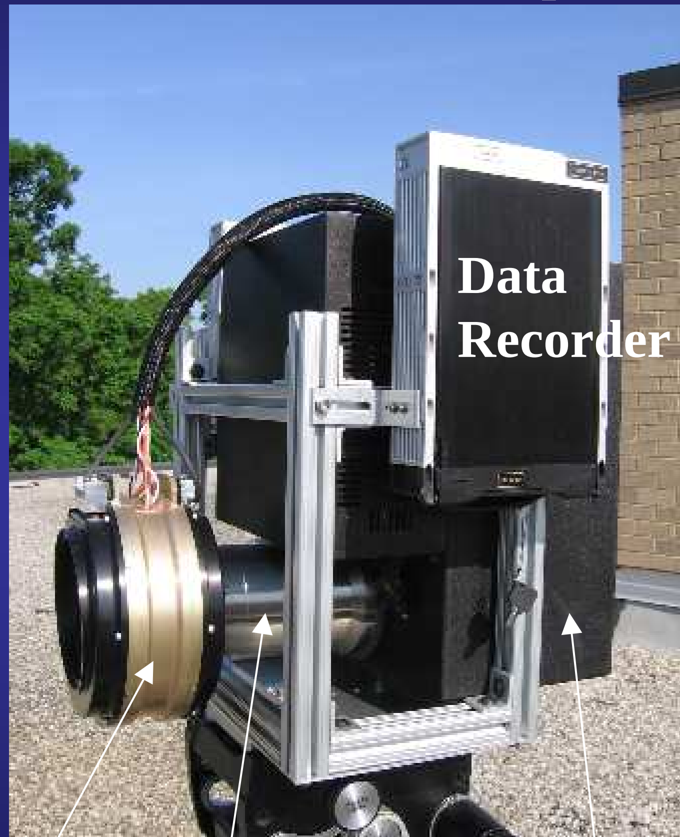
- Diffractive Optical Element (DOE) splits green output into 100 beamlets (~50 nJ @ 20 kHz = 1 mW per beamlet) in a 10 x 10 array. Residual 1064 nm energy is used for polarimetry.

- Returns from individual beamlets are imaged by a 3 inch diameter telescope onto one anode of a 10x10 segmented anode micro-channel plate photomultiplier.

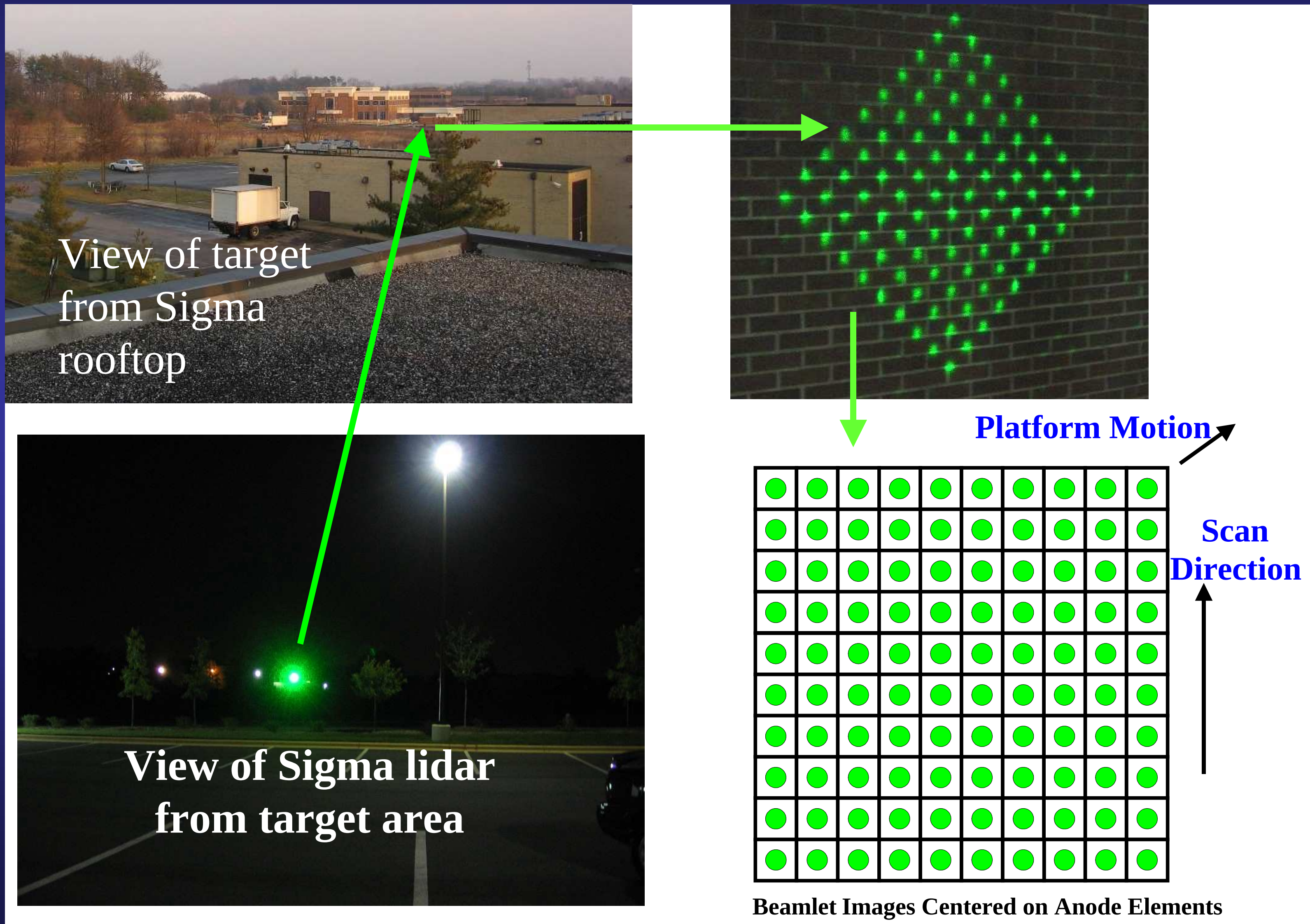
- Each anode output is input to one channel of a 100 channel, high resolution ($\pm$ 92 psec or $\pm$ 1.4cm), multi-stop timer to form a 100 pixel 3D image on each pulse. Individual images are mosaiced together by the aircraft motion and an optical scanner (100 pixels @ 20 kHz = 2 million 3D pixels/sec).

- The high speed, 4" aperture, dual wedge scanner is synchronized to the laser pulse train and can generate a wide variety of patterns. The transmitter and receiver share the telescope and scanner.

Lidar mounted on tripod



100 DOE-generated beamlets are imaged onto individual anodes of a segmented anode microchannel plate photomultiplier.



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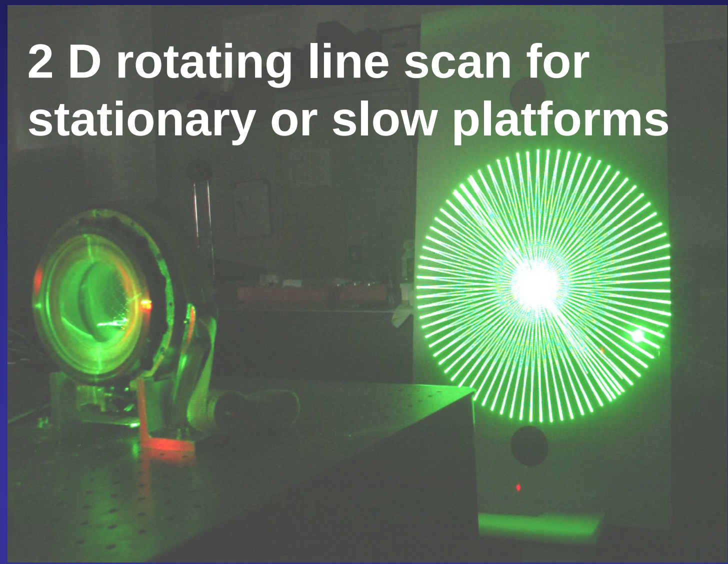
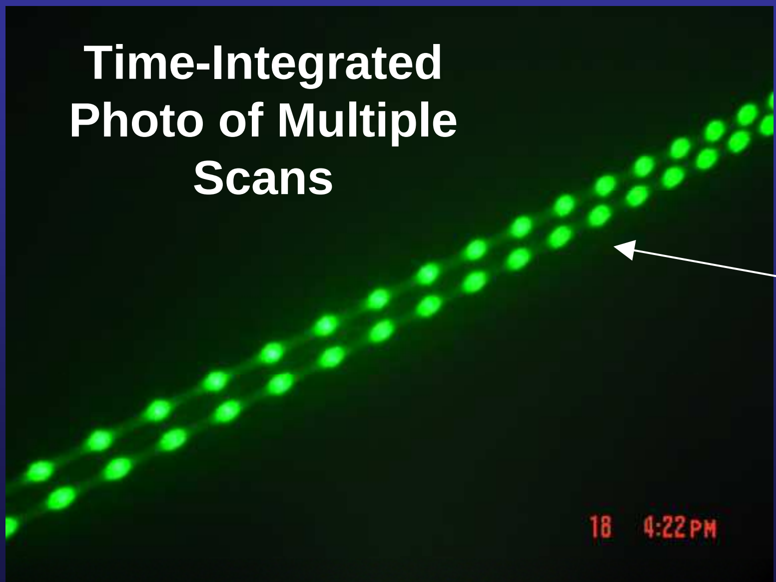
Sigma Dual Wedge Optical Scanner

1 D linear scan for fast-moving aircraft



2 D rotating line scan for stationary or slow platforms

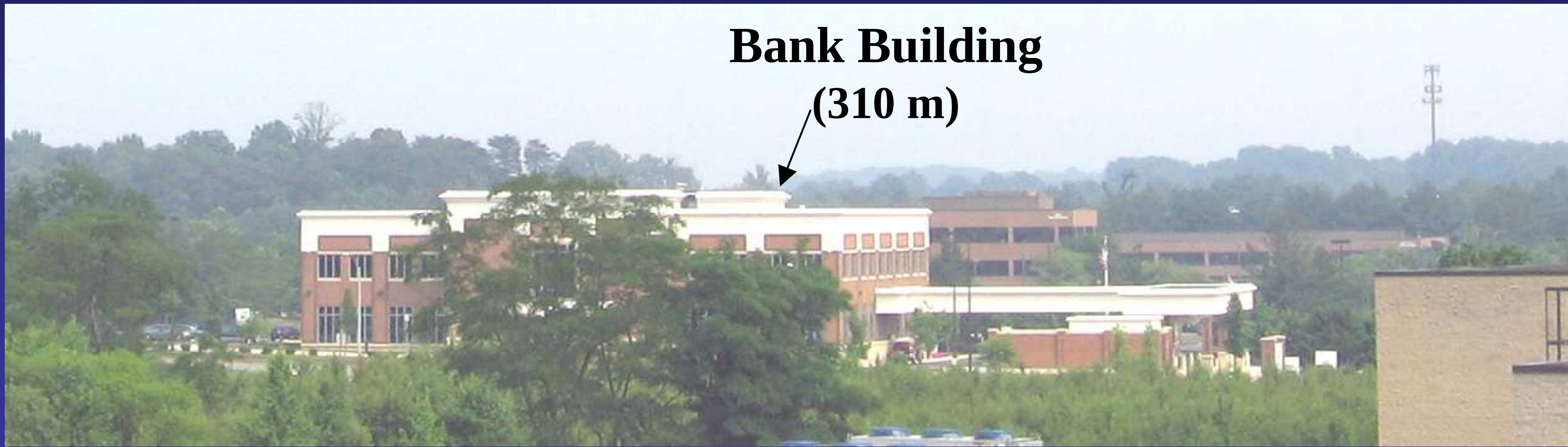


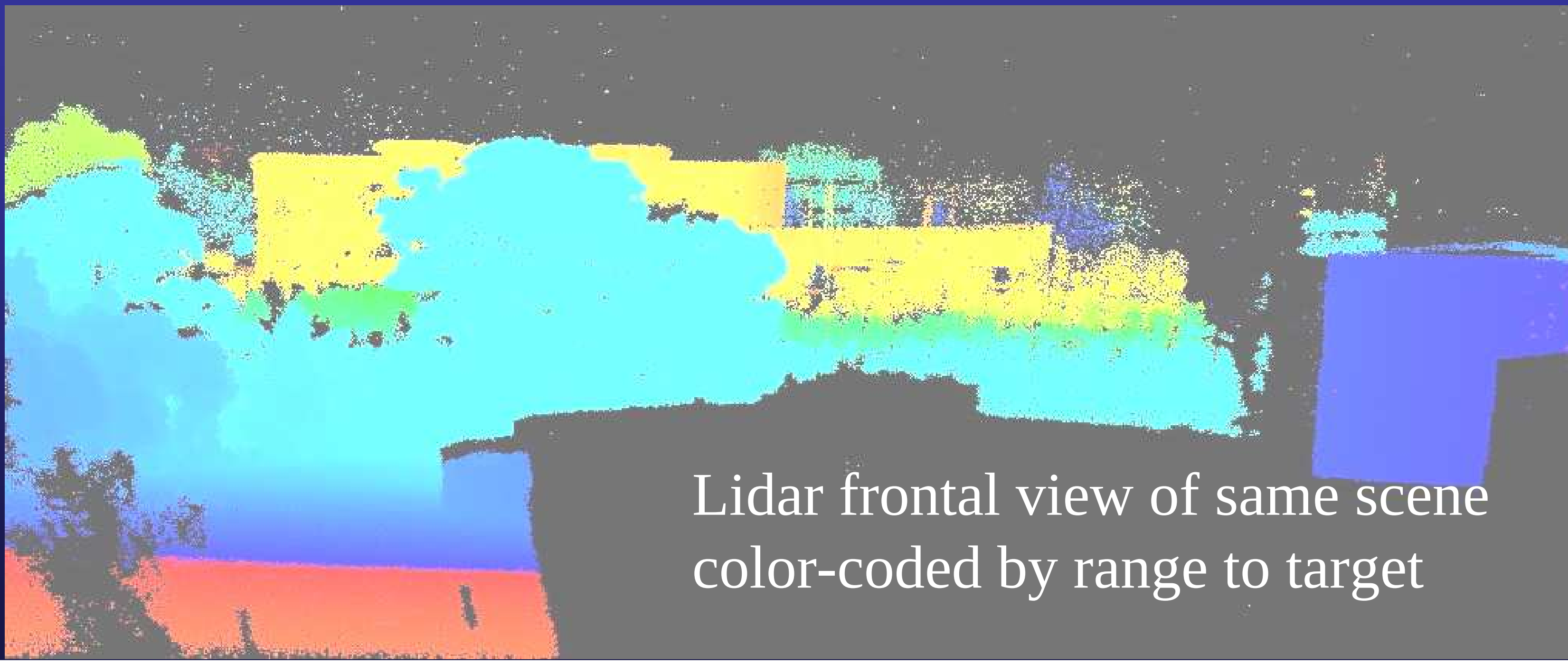
Time-Integrated Photo of Multiple Scans

- **Highly flexible 1D or 2D scan options (linear, conical, rotating line, spiral, etc.)**
- **Synchronization of the scanner to multikilohertz laser pulse train causes beams on successive scans to overlay and reduces ancillary wedge position data storage by 3 orders of magnitude.**
- **Current Maximum Scan Rate: ~25 Hz**
- **Angular Scan Repeatability between Cycles: 1 part in 10^5 or $\pm$0.07 pixel (~1cm @ 1 km altitude)**

Rooftop Testing of 3D Imaging Lidar

Rotating line scan ("3D camera mode")





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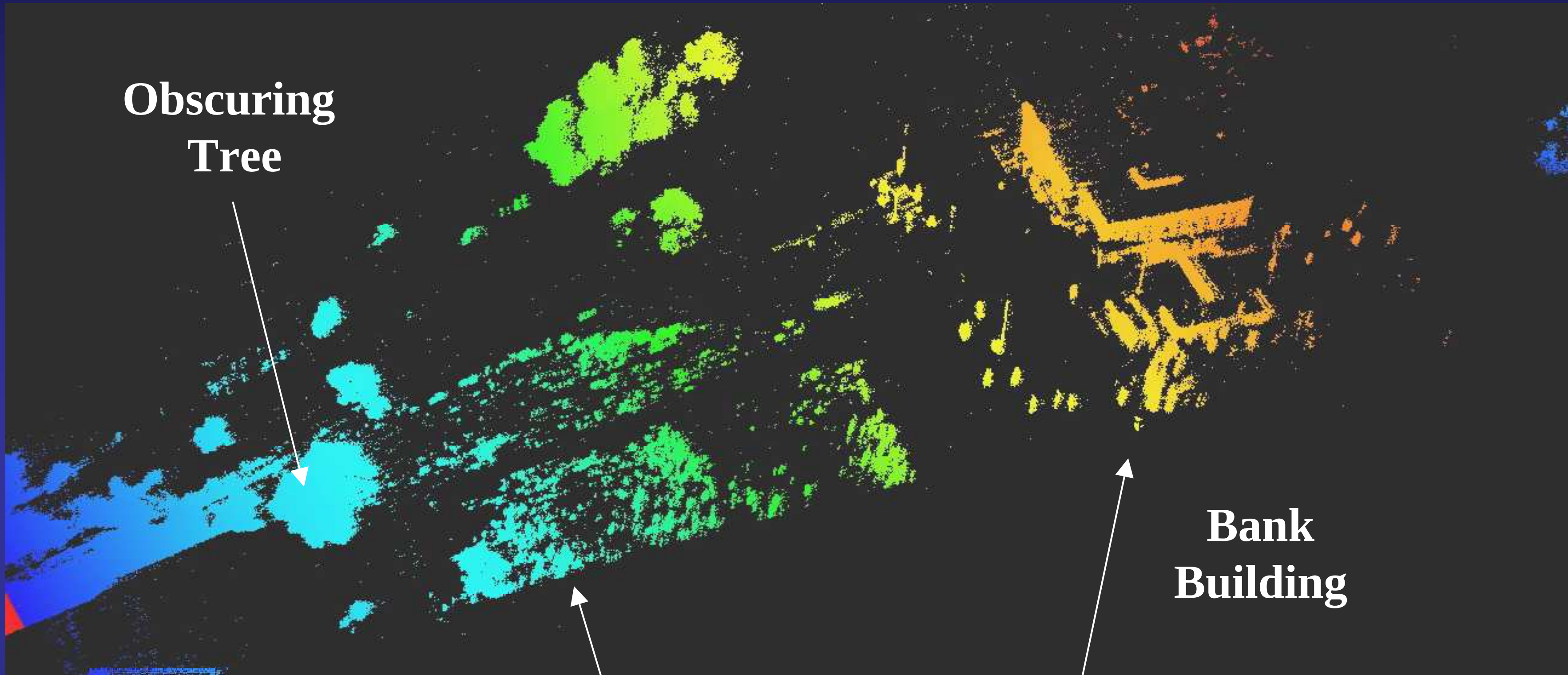
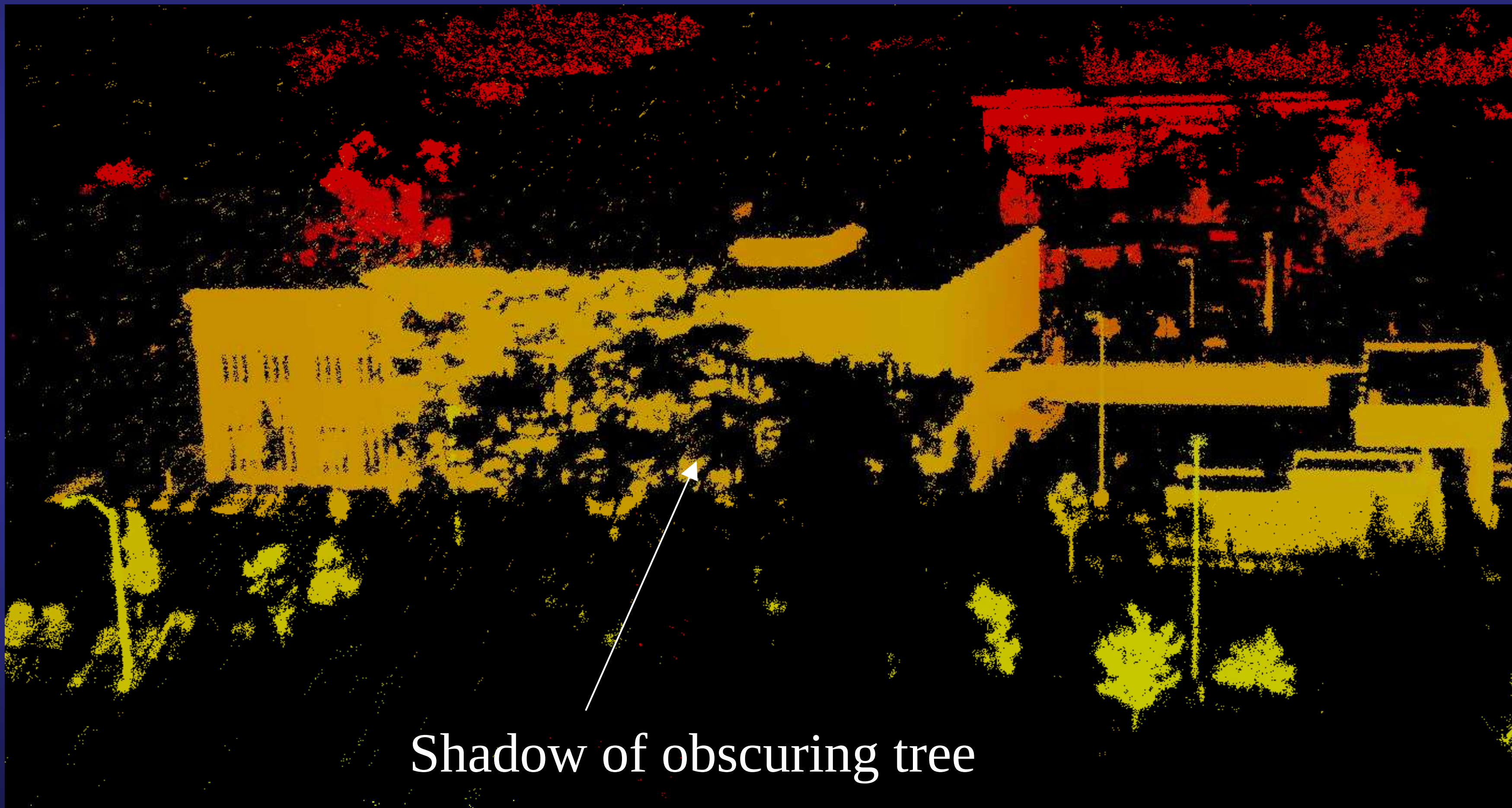
Top View of 3D Lidar Data



Sigma Rooftop

3D Lidar Image of Bank Building

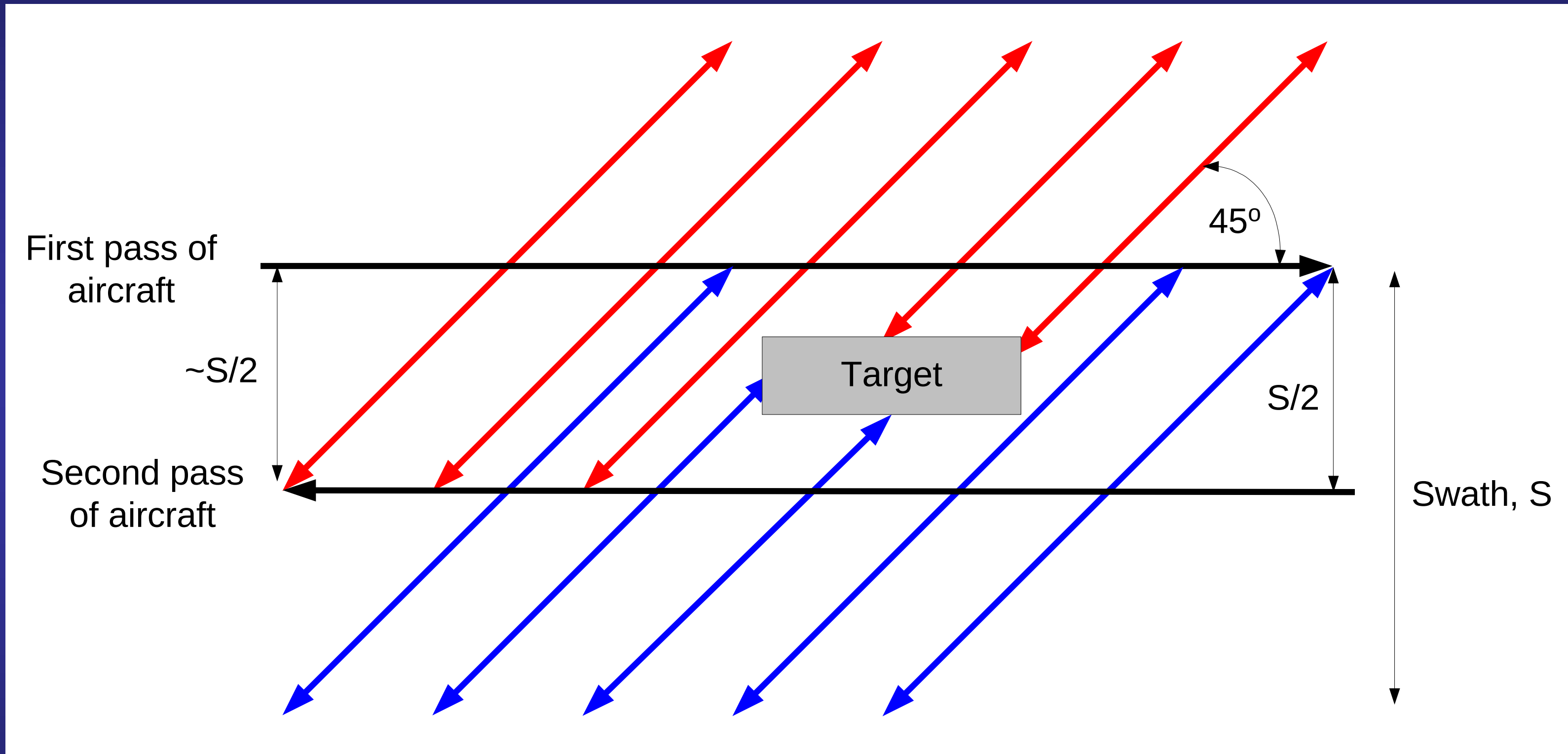


3-D Lidar Image of Parking Lot at 200 m

2nd Generation Flight Tests

- **First flight on August 29, 2007**
  - ~22 minutes of data
- **Initial Targets**
  - Man-made structures (e.g. bridges) to define aircraft heading bias and demonstrate commercial surveying applications.
  - Lakes and reservoirs to define aircraft attitude biases and demonstrate underwater 3D imaging.
  - Treed areas to investigate canopy penetration and utility for forestry management/biomass measurement.
- **The preliminary flight images to follow were taken near noon from an altitude of 0.55 km (1800 ft). <u>Data has not been corrected for attitude and heading biases and the images are derived from a single pass over the scene.</u>**

Flight and Scan Pattern for Fast-Moving Aircraft

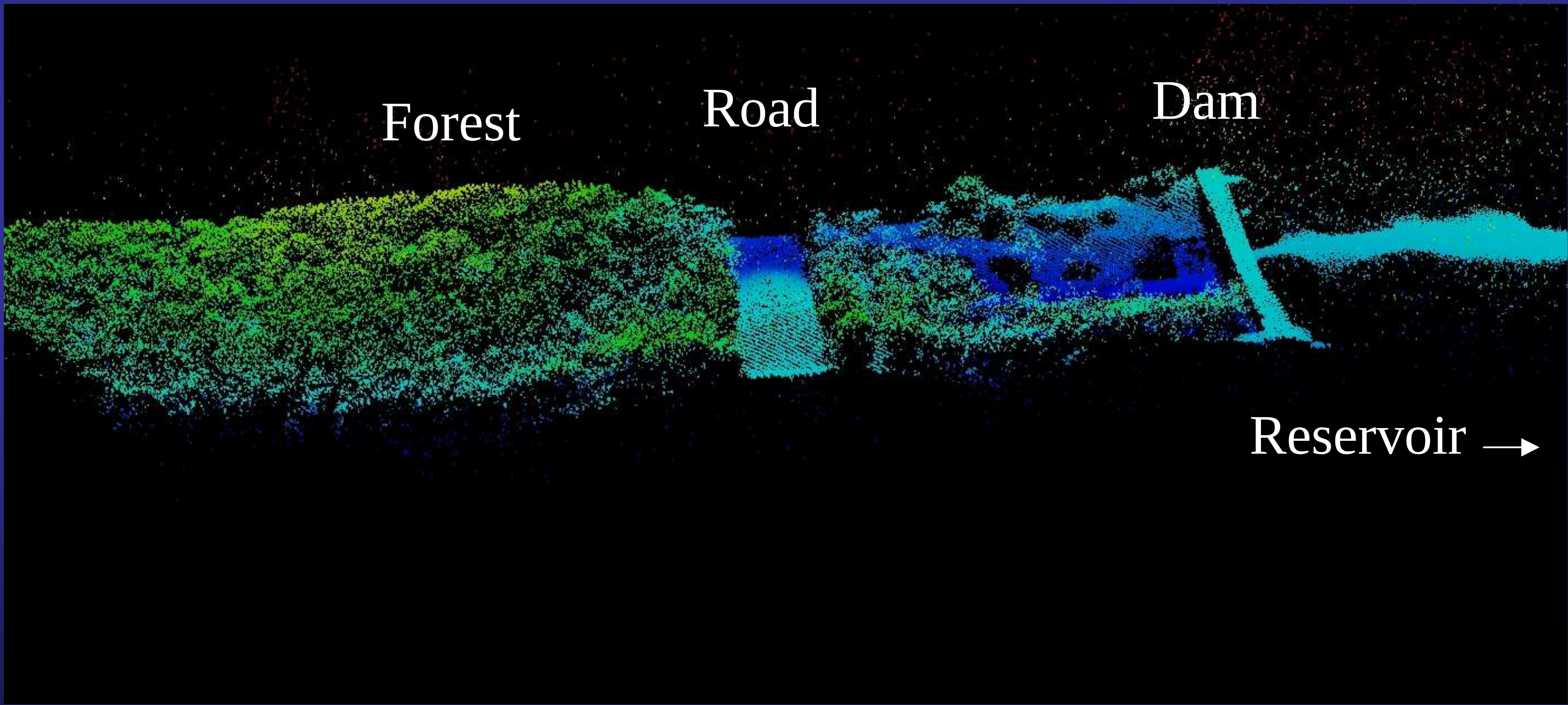


For contiguous mapping and viewing of all sides of an object, we :

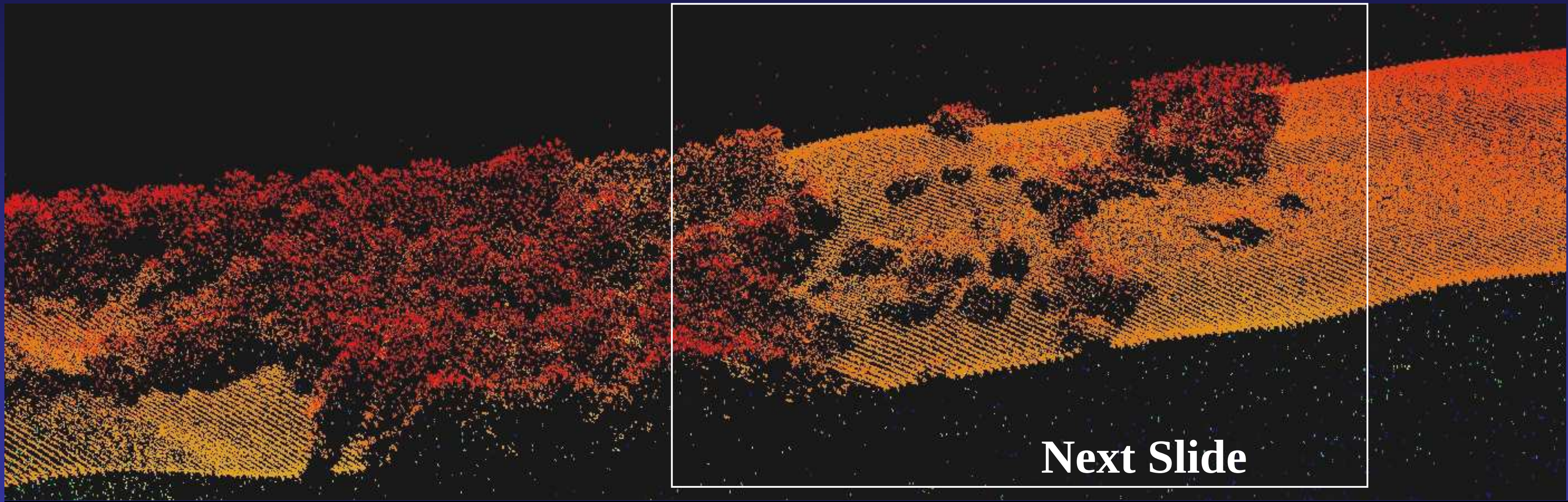
•Use linear scan at 45º to the flight path.

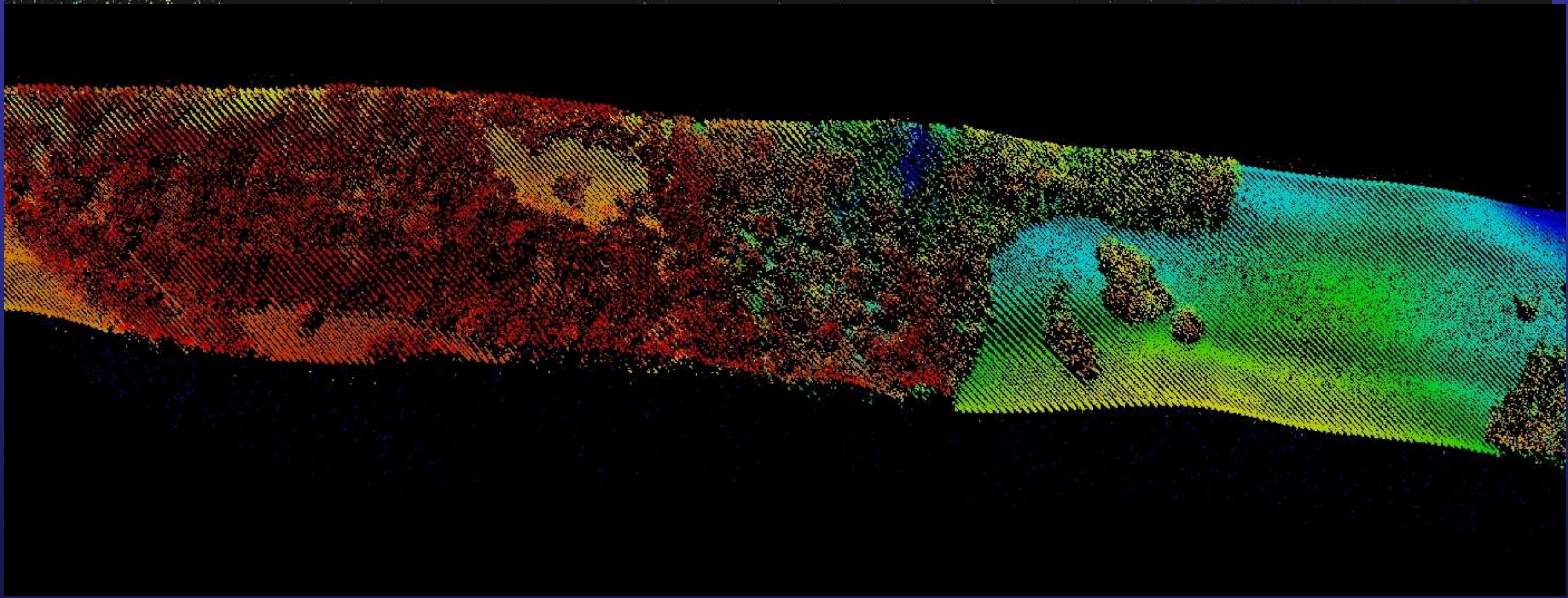
• Ensure that subsequent passes are separated by roughly half the swath width with the aircraft flying in the opposite direction.

Lidar View of Triadelphia Reservoir, MD (single overflight)

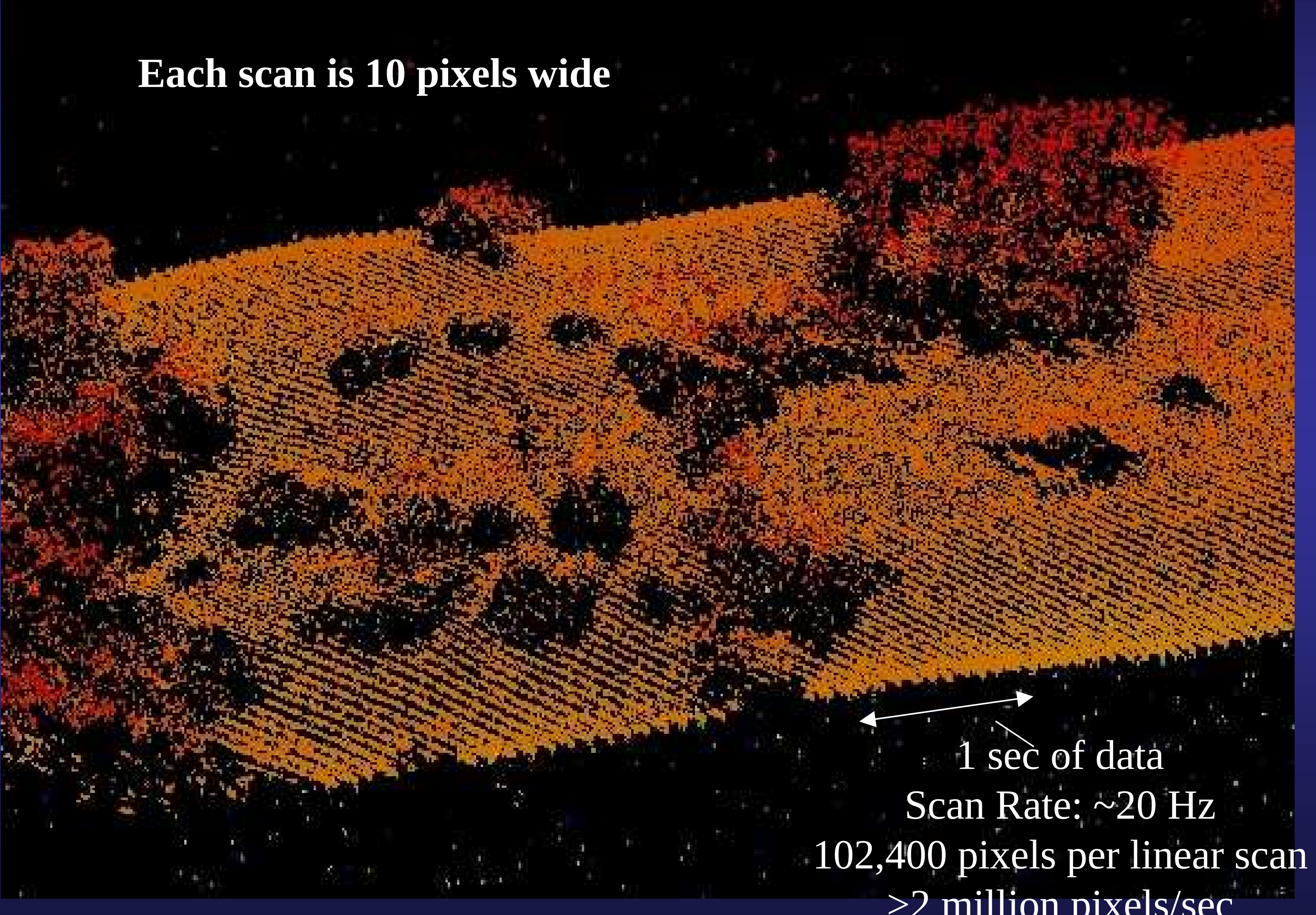


Treed Areas





Closeup view showing scan lines at 45º to flight path



Scan Rate: ~20 Hz
102,400 pixels per linear scan
>2 million pixels/sec

SUMMARY

- Photon-counting is the most efficient lidar approach for generating large scale topographic maps because it requires only one received photon per range measurement.
- Single photon sensitivity, combined with a fast multistop detector and receiver, permits daylight operation with wide temporal gates and improves penetration of porous obscurants (fog, dust, water, tree canopies, etc.)
- Over the next few months, we will explore the full capabilities of the second generation system through a series of flight tests.