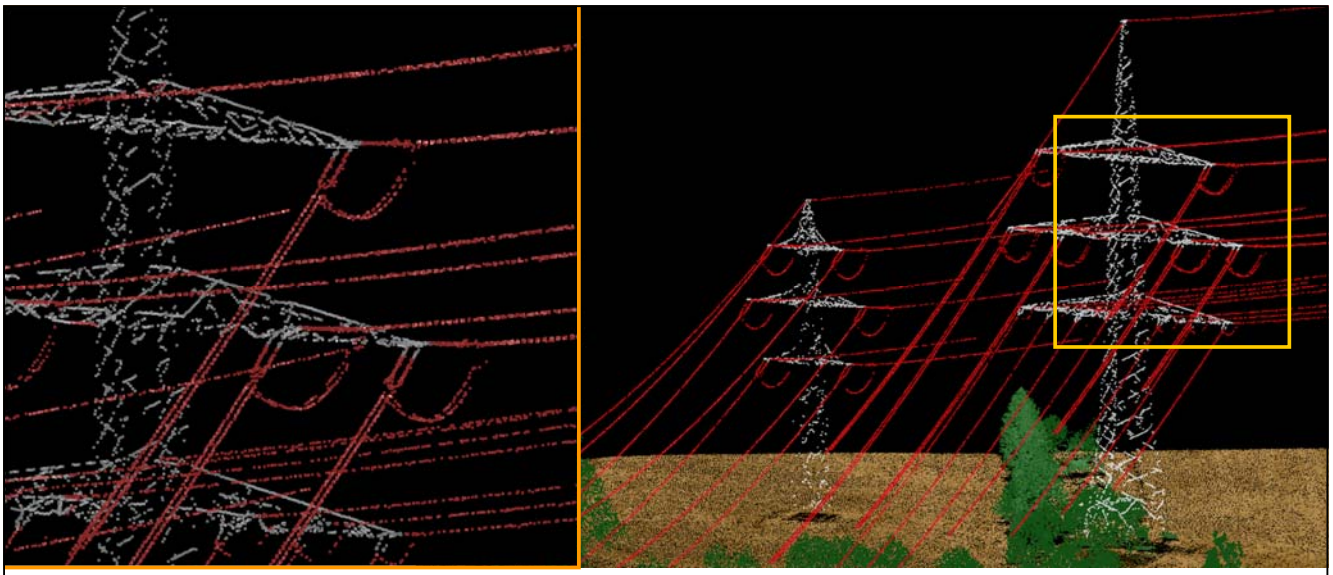


Leica ALS70:
Point Density Multiplication for High-Density Surface Acquisition

Ron Roth, Vice President- Airborne LIDAR
Hexagon Geosystems Geospatial Solutions Division

Topics

Introduction

Historical perspective on LIDAR development

- LIDAR market development
- LIDAR technology development

Recent developments

- Multiple output scanners
- Reduced measurement cycle overhead

Areas for continued interest

Additional thoughts: pixel-by-pixel automated surface extraction

Introduction

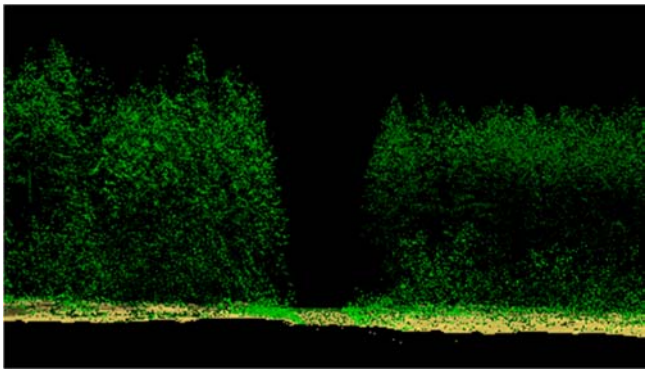
Rapid growth of airborne LIDAR since mid 1990s

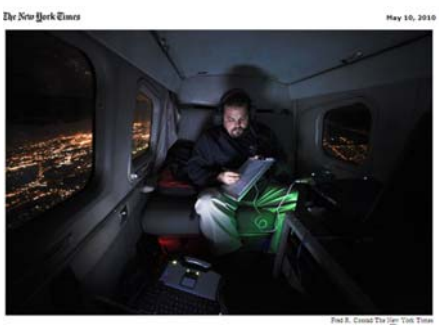
- Installed base
- Capabilities

Diverted attention from development of photogrammetric surface extraction

Recent developments show great promise for photogrammetric surface extraction, but…

- Airborne LIDAR still better at extracting forest floor
- Airborne LIDAR still better at certain linear features (e.g., power transmission lines)
- Airborne LIDAR offers 24-hour operating envelope





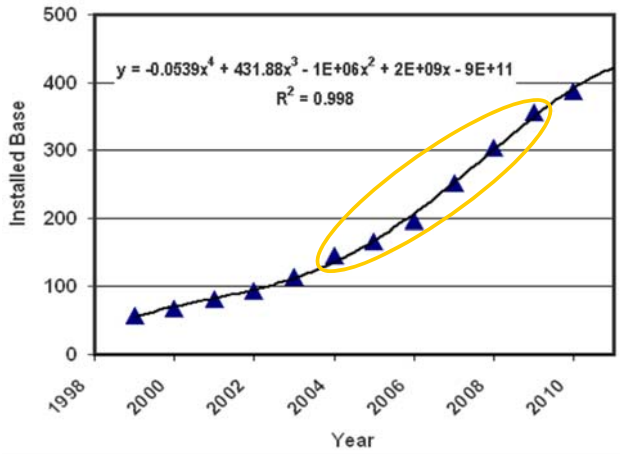
LIDAR market development

Rapid growth 2004-2009

Some leveling in recent years

- World economic issues
- Possible saturation

Some market recovery observed in 2011, though still not up to pre-2010 levels



LIDAR technology development

Historical improvements

- Accuracy
- Pulse rate
- Minimum vertical separation distance
- Full waveform digitization (FWD) acquisition and exploitation
- Scan pattern control (pattern shape and scan rate)

Areas with greatest improvement

- Accuracy
- Pulse rate

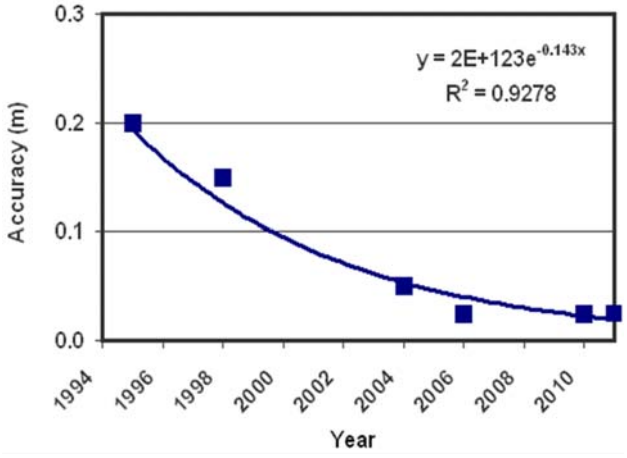
Accuracy leveling over recent years

~ 50% reduction every 5 years

- Rapid improvement in late 1990s
- Slowing absolute rate of improvement in recent years

Limiting factors

- Airborne GNSS accuracy
- Availability of high accuracy ground control over large job sites



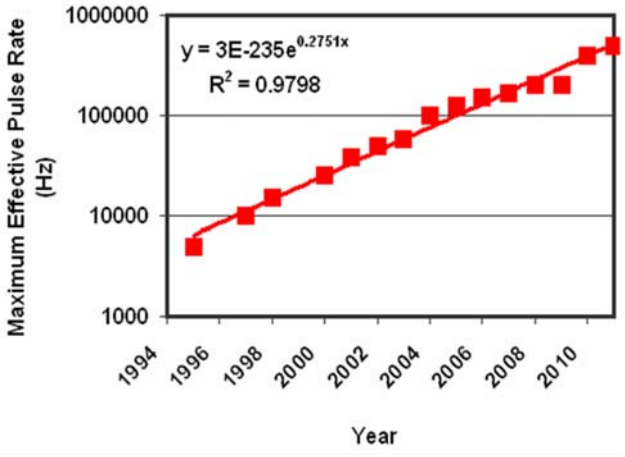
Pulse rate improvement still steady

Pulse rate as indicator of productivity

- Intuitive: more points per hour ➔ less hours flying
- Less intuitive #1: more points per hour ➔ wider swath in each flight line ➔ less side overlap (%) to overcome navigation error ➔ fewer flight lines
- Less intuitive #2: same point density from higher altitude ➔ reduced swath width variation due to terrain elevation changes ➔ less side overlap (%) to overcome swath width variation ➔ fewer flight lines

New nomenclature: “effective pulse rate” accommodates:

- Effect of duty cycle in some scanning systems
- Effect of multiple output scanning systems



Recent developments: growth in pulse rate

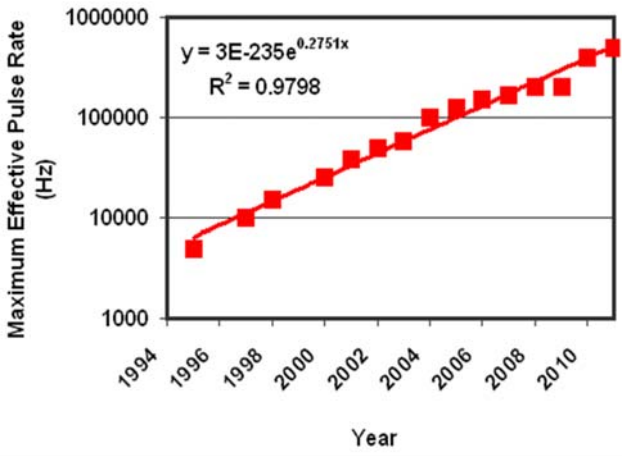
Up until ~2004: limited by

- Max pulse rates of available lasers
- Relatively high end-of-cycle timing overhead
- Fly lower to pulse faster

2006 – 2009: Multiple Pulses in Air (MPiA, a.k.a., “CMP”, “MTA”)

- Allowed laser to be fired before reflection from previous pulse is received
- Doubles the pulse rate for a given flying height
- Practical to achieve high pulse rates at reasonable altitudes
- Limitations
  - Pulse consistency
  - Adequate pulse energy

2009: first dual-output scanners announced



Recent developments: dual-output systems

Contributes in two areas:

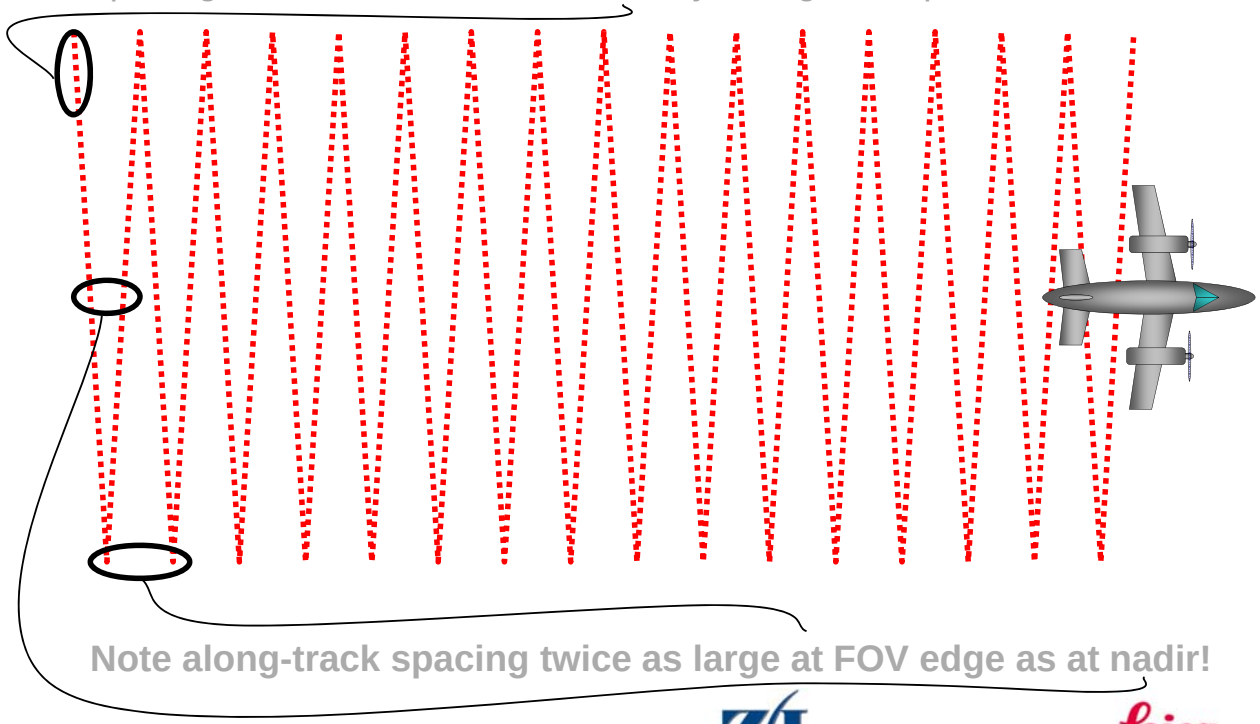
- Doubles pulse rate
- Doubles scan rate
- Remember: scan rate should double for each quadrupling of pulse rate

Three embodiments

- Two complete / nearly complete systems in same aircraft
- Multiple scan heads in single scanner
- Single laser, single scanner, single receiver

Single-output limits along-track spacing

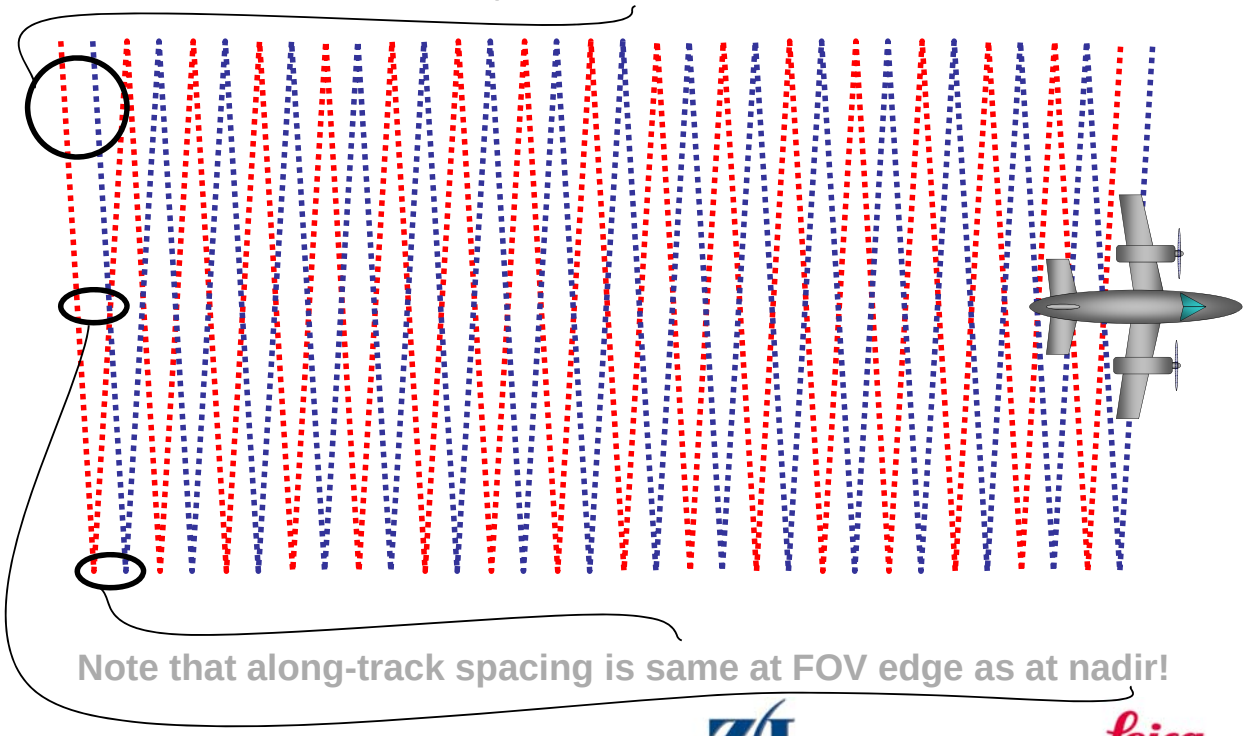
better spacing is in cross-track direction only with greater pulse rate



Note along-track spacing twice as large at FOV edge as at nadir!

Dual-output scanning doubles scan rate, pulse rate

doubles effective scan rate and pulse rate



Note that along-track spacing is same at FOV edge as at nadir!

ALS70 and Point Density Multiplier

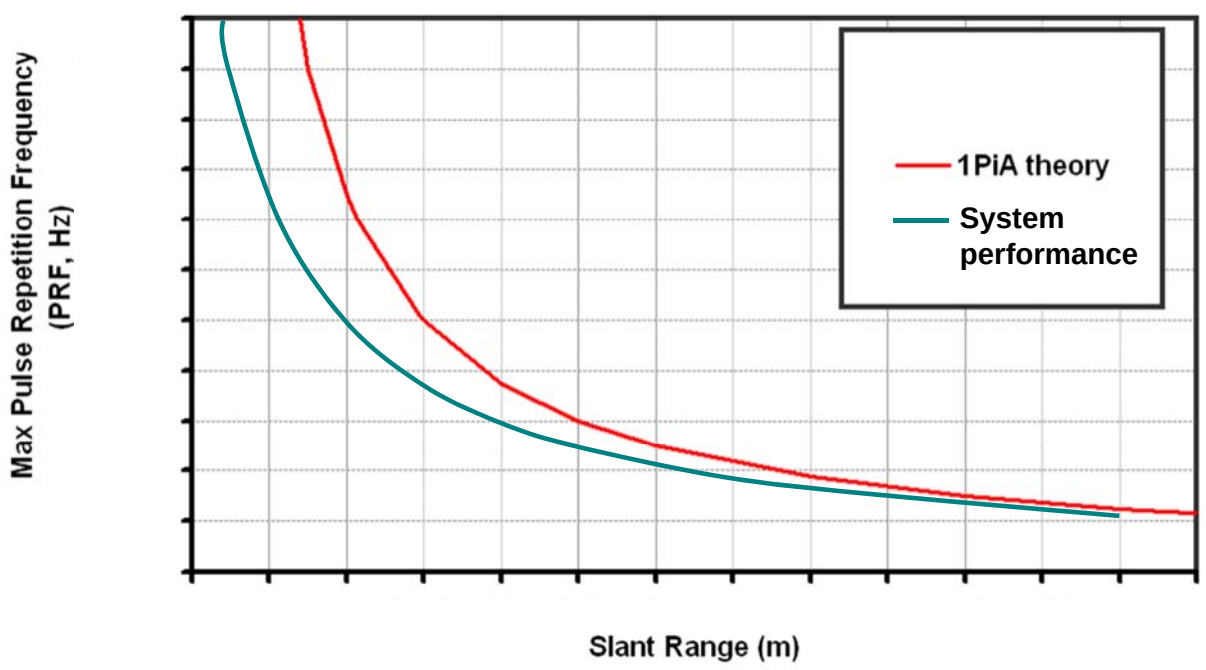
Dual-output system

- Single laser, single scanner, single receiver
- Split laser output, dual detectors

Reduced-overhead range measurement electronics

- Operate closer to theoretical limits imposed by speed of light
- Faster pulse rate at any given flying height
- Greater range accommodation for greater tolerance of terrain elevation changes
- Lowers PCB count versus previous generation
- Reduced minimum vertical separation
- Unlimited returns from each outbound laser pulse

Reduced measurement cycle overhead



Challenges in implementing multiple-output scanning

Adequate focal plane size to allow off-axis detector placement

Optical alignment

- Maintaining stable alignment of the two output beams
- Crosstalk – receivers can “see” opposite laser if laser divergence is too large, receiver IFOV is too large and/or lasers not separated by large enough angle

Boresight alignment/calibration

- Similar to two systems operating simultaneously, but…
- Higher point density makes any anomalies more visible as a systematic effect

Mission planning

- System settings and resulting scan patterns must reflect use of dual-outputs

Keeping scan patterns out-of-phase

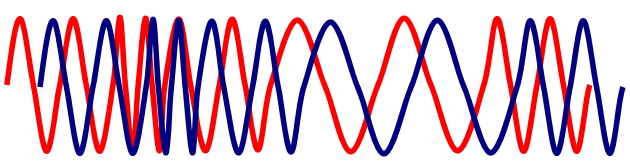
Scan pattern coordination in dual-output scanners

Along-track spacing affected by aircraft speed decrease (compression) and increase (stretching); pattern of compression and stretching is shifted in along-track direction for two scanners' outputs

Autoscan feature makes subtle adjustments in scan rate to keep scan patterns out of phase

- Ground speed
- Height above ground

Similar effect due to aircraft pitch variations solved using PAV80



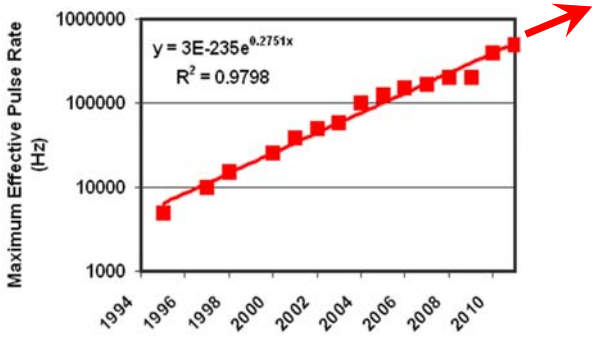
Areas for continued interested: scaling the architecture

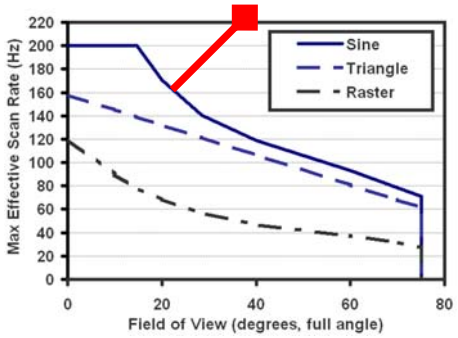
More outputs ➔ larger focal plane size in receiver optics ➔ relatively easy (compared to large format camera)

More pulses in the air ➔ possible with new electronic design

More laser pulse energy ➔ more difficult

- Same pulse energy in each output required, but more outputs
- Compounded by MPiA, which requires high pulse energy at high pulse rates





Additional thoughts: surface extraction from imagery

Historically limited by

- Algorithm complexity
- Available computing power

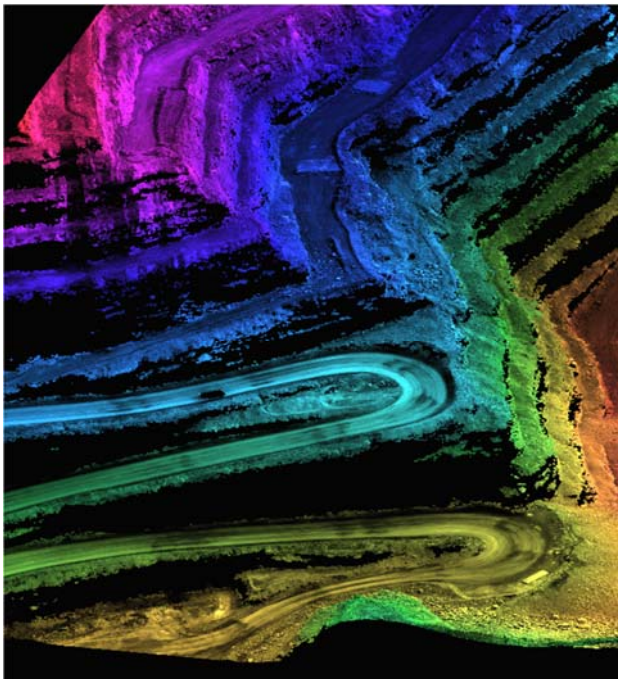
Recent advancements

- Advanced algorithms (e.g., SGM)
- Low-cost computational power

Point acquisition rate (raw data collection in air)

- ALS70-HP example: ***250 kHz laser x 2 outputs = 500 kHz***
- ADS80 example: ***12,000 pixels/line x 1,000 lines/sec x 0.80 match rate = 9.6 MHz!!!***

Implication: careful selection of sensor based on mission requirements



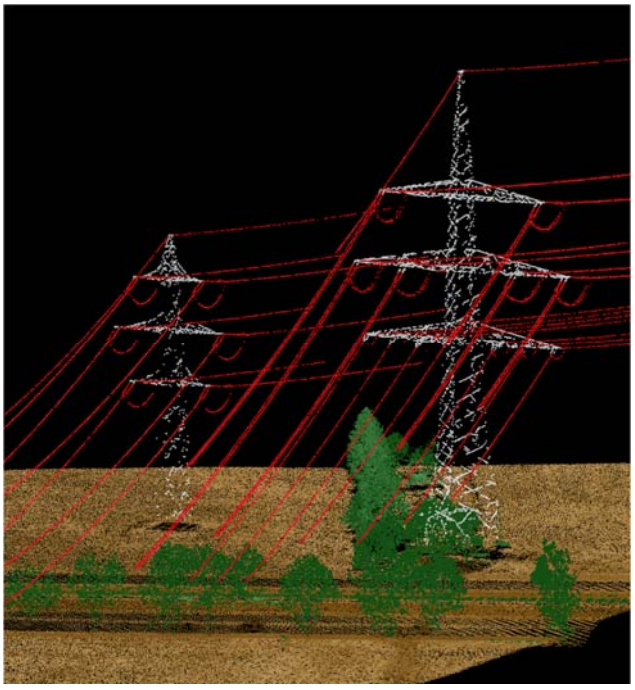
Conclusions

Dual output scanning system significantly enhances data acquisition productivity

ALS70 presents a simple embodiment of dual-output scanner technology

ALS70 represents an excellent platform for potential scaling of multiple-output scanning technology

Point cloud generation from imagery is practical and powerful under a reasonable variety circumstances



Vielen Dank!
Thank you!