HEXAGON
海克斯康

塑造智慧变革

北京
国家会议中心
2018年
9月10-12日
2018.hexagonchina.com.cn

Creating the Future: the prospect of Leica single-photon LiDAR technology
创造未来：徕卡单光子激光雷达技术发展前景

Zhigang Pan – Geoscientist（地球学家）
Ron Roth – Product Manager, Airborne Topographic LiDAR（机载激光雷达产品经理）

12th Sep, 2018

海克斯康 HEXAGON

Single-photon LiDAR technology: how it is creating the future of large-area survey
单光子激光雷达技术：如何实现大面积区域的测量

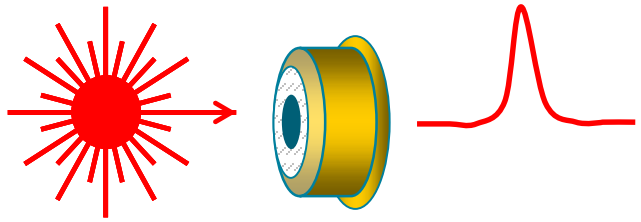
- What is single-photon technology?
- Why is it unique?
- How does it compare to conventional linear-mode lidar technology?
- What can be accomplished with it?
- Where has is been used?

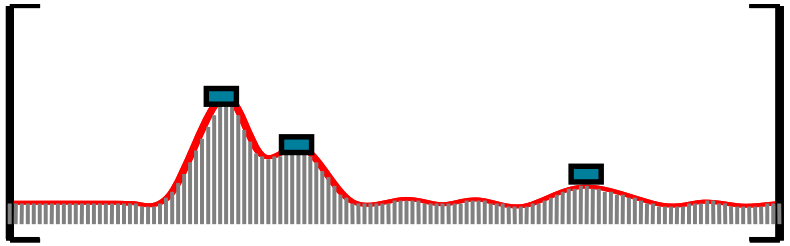
- 什么是单光子技术？
- 为什么会与众不同？
- 与传统线性激光雷达相比有何不同？
- 单光子能够实现什么？
- 能够用于哪些领域？

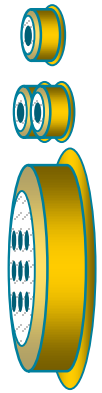
海克斯康 HEXAGON

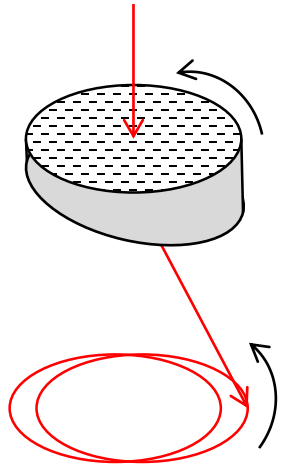
Breaking down airborne LiDAR into constituent technologies
将机载激光雷达分解为多种技术

- Detection methodology
  检测方法
- Rangefinding methodology
  测距方法
- Detector massing
  探测器集结
- Scanning method
  扫描方式









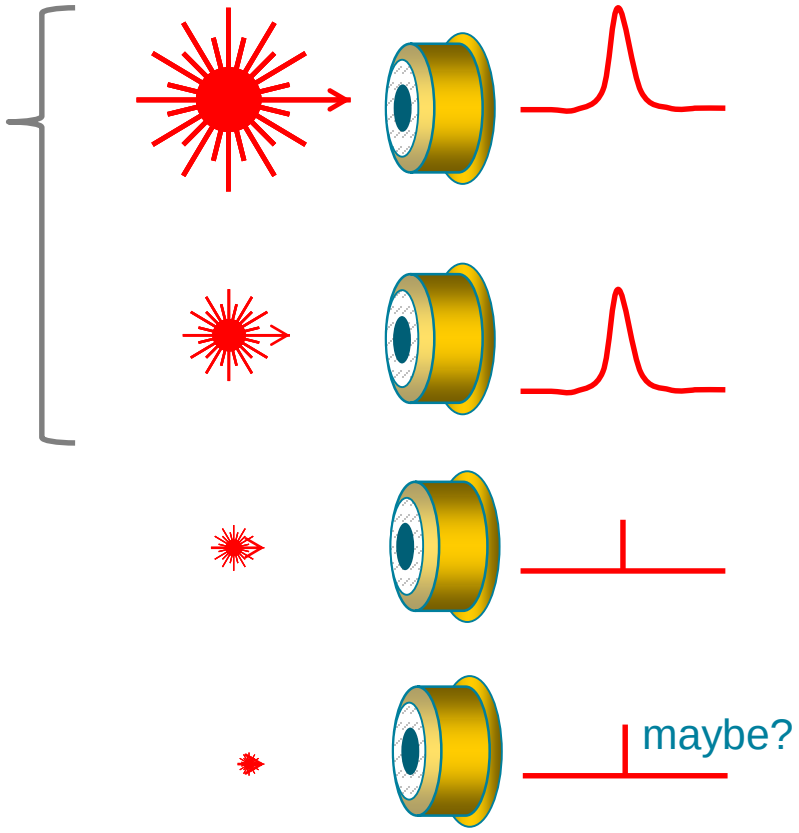
海克斯康 HEXAGON

Detection method is what distinguishes single-photon from other LiDAR
单光子与其他激光雷达在探测方式上的区别

- Linear-mode (conventional) ➔ the more photons that come back, the stronger the indicated return signal (i.e., intensity proportional to reflectivity)
- 线性模式（常规）：返回的光子越多，显示的信号越强（强度与反射率成正比）

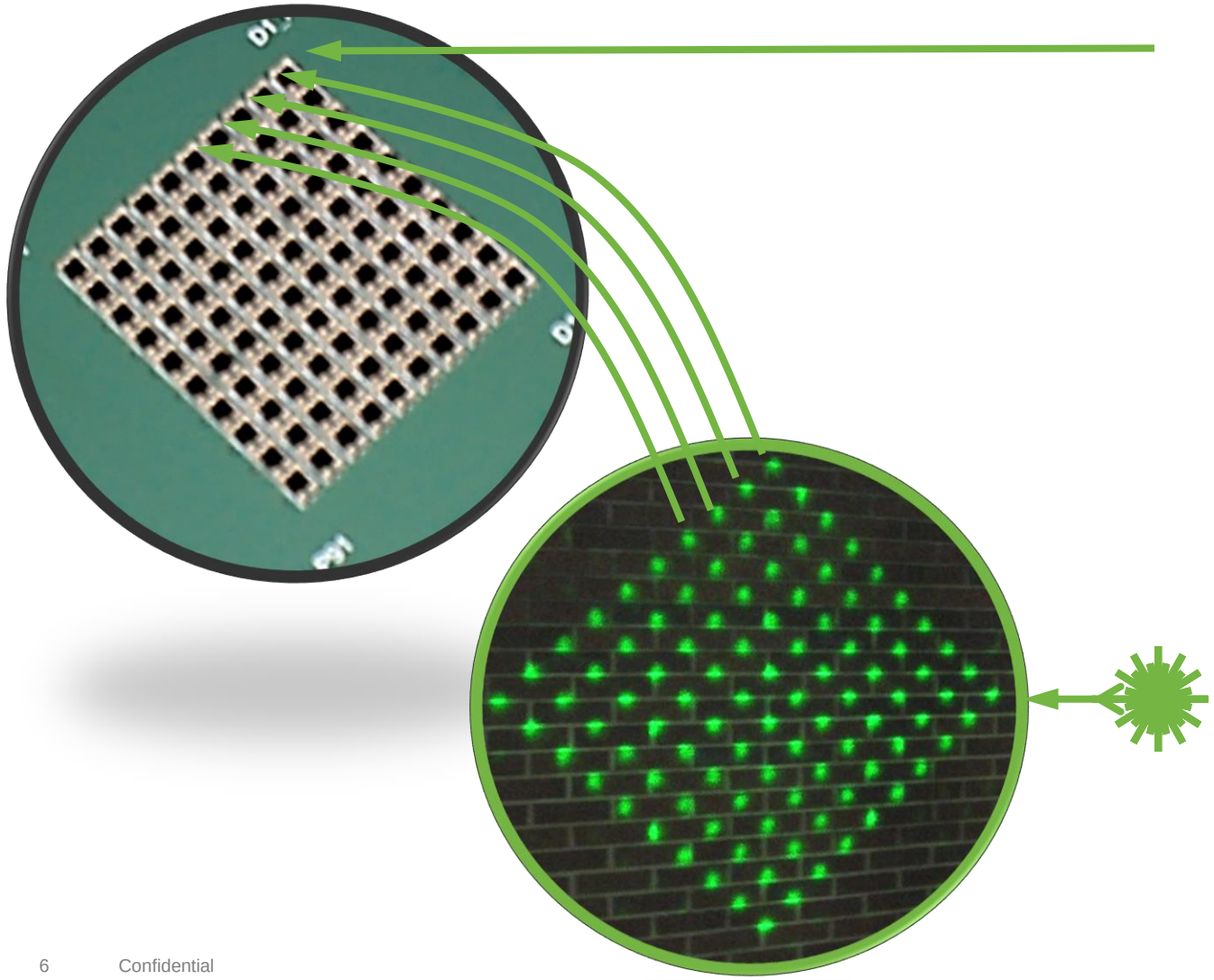
- Single-photon ➔ like linear-mode, but with much higher amplification and lower laser outputs required
- 单光子：与线性模式类似，但是需要更高的放大以及更低的激光输出

- Geiger-mode ➔ very little laser output required, but “probabilistic” detection (…if one photon hits the detector, you might get a detection… but then the detector has to be “quenched” before the next laser shot is fired; accumulate data from many shots to pull target range out of noise)
- 盖格模式：非常低的激光输出，但是以概率检测（假设一个光子被探测器接收，将得到一个检测信号，但是直至下一束激光发射之前，这个探测器将会致盲一段时间；通过多次射击的数据积累，将目标从噪声中区分开来）



海克斯康 HEXAGON

Why is single-photon technology unique?
为什么单光子技术会与众不同?



- Single-Photon Avalanche Diode (SPAD) detectors are far more sensitive than Avalanche Photo Diode (APD) detectors used in linear-mode LiDAR systems
- 单光子中的雪崩二级管（SPAD）探测器比线性激光雷达中的雪崩光电二极管（APD）探测器要灵敏的多

- Less laser output required for detection of a target
- 检测一个目标所需的激光输出更少

- Output from a single laser pulse can be split to illuminate multiple locations on the ground, each illuminating an individual detector element
- 单个脉冲对应输出到单独的接收器单元上

海克斯康 HEXAGON

Sensitivity of single-photon put into perspective: at 4000m AGL
4000m AGL下，单光子的灵敏度

- SPL100 (single-photon)
  - 5 watt laser output
  - Effective pulse rate 5000 kHz

SPL100（单光子）

5瓦特激光输出

有效脉冲频率 5000 kHz

- TerrainMapper (linear-mode)
  - 20 watt laser output
  - Effective pulse rate 500 kHz

TerrainMapper（线性）

20瓦特激光输出

有效脉冲频率 500 kHz

- Single-photon technology delivers 10x the effective pulse rate of linear-mode systems, with ¼ the laser output!
- 相比线性激光雷达，单光子技术将有效脉冲频率提升了10倍，且激光输出功率仅是线性激光雷达的1/4！

海克斯康 HEXAGON

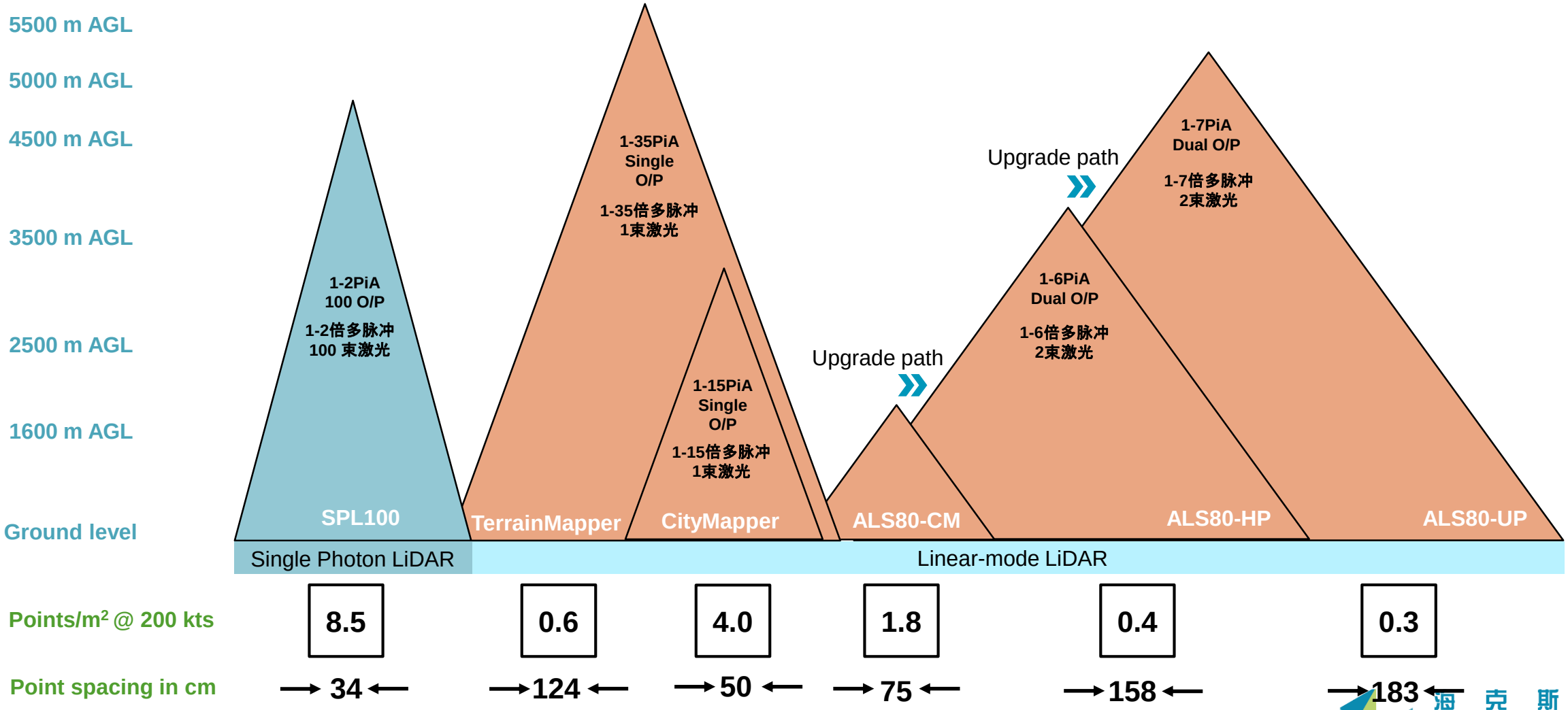
How do single-photon and linear-mode technologies compare?
如何比较单光子技术和线性技术？

- A brief look at performance parameters of representative systems
- 简短比较一下典型的产品性能参数

Parameter	SPL100	TerrainMapper
Effective pulse rate (kHz @ 4000m AGL)	5000	500
Effective pulse rate (kHz @ 2000m AGL)	6000	2000
Accuracy (RMSEz, cm)	6-10	<3-5
Intensity data (dynamic range, bits)	~4	14

参数	SPL100	TerrainMapper
有效脉冲频率 (kHz @ 4000m AGL)	5000	500
有效脉冲频率 (kHz @ 2000m AGL)	6000	2000
精度 (RMSEz, cm)	6-10	<3-5
强度数据 (动态范围, 比特)	~4	14

Topographic LiDAR Products: Where do they all fit?
地形激光雷达产品都适合用于哪些方面？



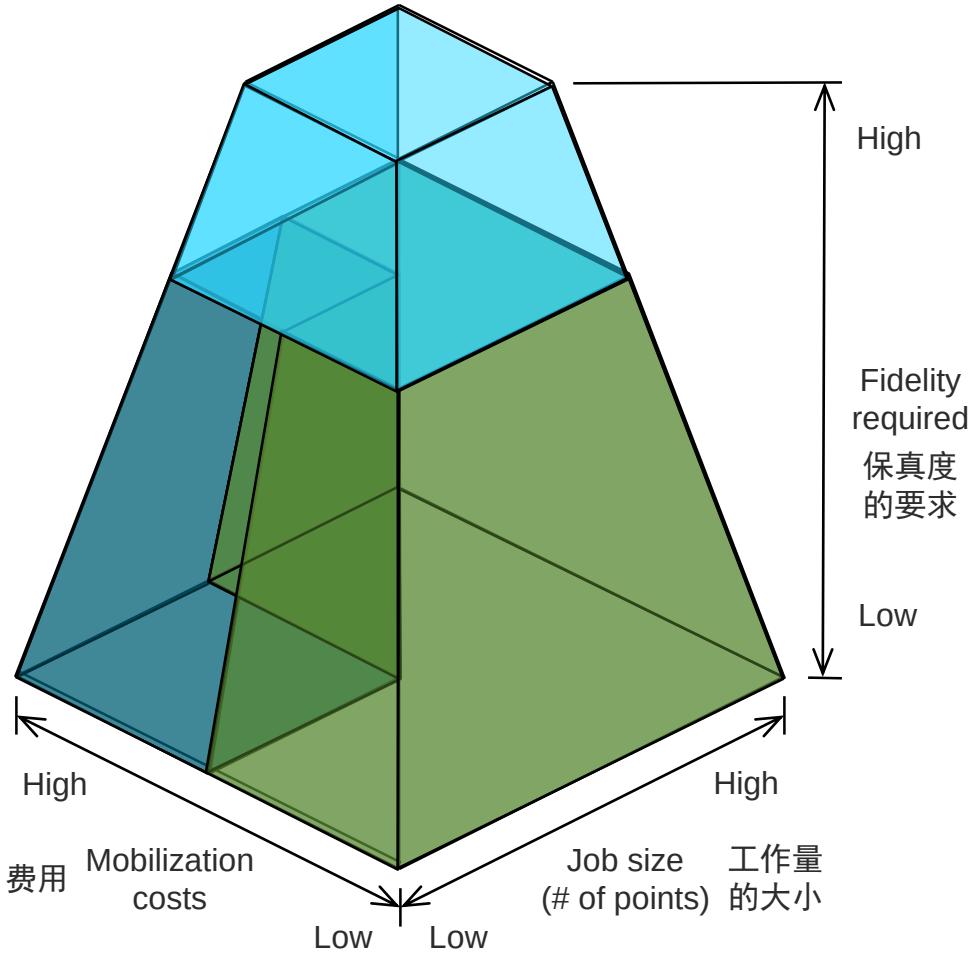
How to employ single-photon technology: market segmentation
如何使用单光子技术：市场细分

- Light Blue = can only be satisfied by linear-mode systems
- Green = can be satisfied single-photon technology
- Dark Blue = can be satisfied by either system, but may not be the best use of capital for SPL technology

- 淡蓝色 = 只能满足线性模式的系统
- 绿色 = 能够满足单光子技术
- 深蓝色 = 满足任何一个系统，但对于SPL技术来说不是最佳首选

- Single-photon technology is best used for data acquisition where higher point densities are required over very large areas (provincial to continental scale)

- 单光子技术最适合用于高点密度需求、大面积区域的数据采集 (规模从省级到整个大陆)



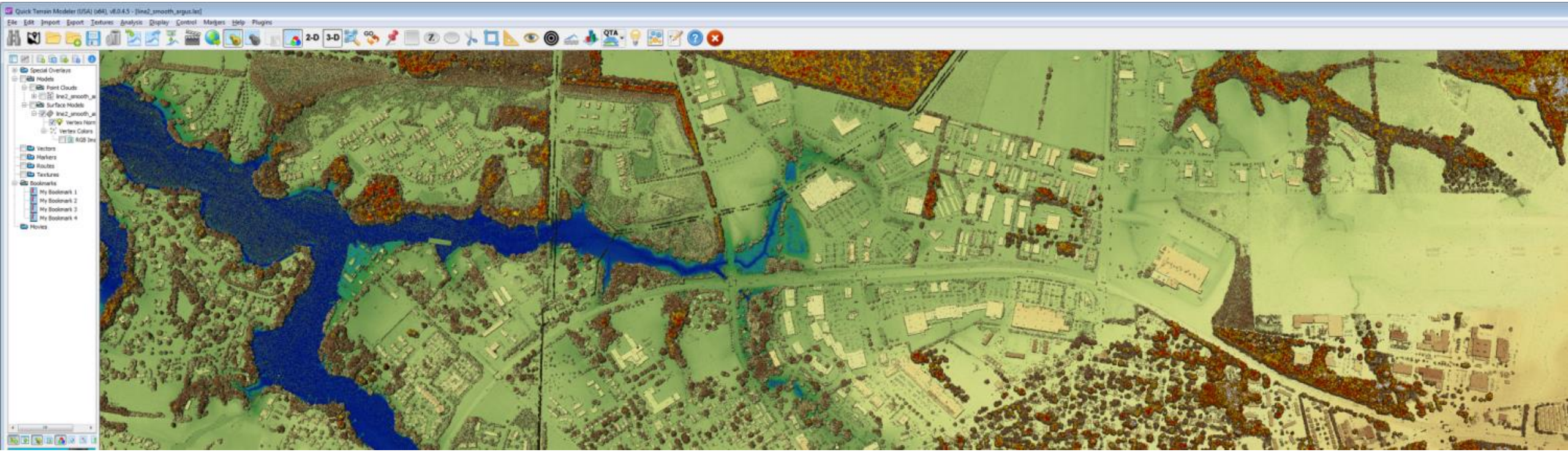
海克斯康 HEXAGON

Where is single-photon technology being used?
在哪些方面可以运用到单光子技术

Project Location 项目地点	Total Area (km^2) 总面积	Point Density ($points/m^2$)　点密度	Application 应用
Northwest USA	<70	>20	High Density point cloud (20+ pts/m2) over forested area for: tree height, inventory models, efficiency of collection 高密度点云获取森林区域：树木高度、库存模型、收集效率
Finland (FGI/MML)	~220	>8, >35	Four areas have been targeted by NLS Finland and the Finnish Geodetic Institute, Espoo, Helsinki, Evo, and Lahti for evaluation of SPL data at 8, 35 and "extreme" points per square meter and one area, Akaa, at 8 points per square meter. 针对4个区域进行了SPL数据评估，每平方米8、35个点
VA, WV, PA USA	1350	>20	Foliage penetration　树叶穿透
MN USA	2939	>12	Forest inventory which will be used to update regional forest cover type maps and to evaluate forest conditions and trends for timber production, wildlife habitat, forest health, water quality, etc. This data will also be used by non DNR citizens, scientists, forest land owners and land managers 森林清查将用于更新区域森林覆盖类型地图，评估森林状况和木材生产、野生动物栖息地、森林健康、水质等方面的趋势。非DNR公民、科学家、森林土地所有者和土地管理者也将使用这些数据
Navarra, Spain	10850	>11	Base mapping　基础制图
Ontario, Canada	75000 (1st year, all years >450000)	25	Forest inventory　森林调查
Southern US	2203	>45	Power line mapping for asset vegetation management　电力线测绘、植被资产管理
Hawaii USA	10442	8	USGS 3D elevation mapping program　USGS三维高程制图程序
South Dakota USA	10218	8	USGS 3D elevation mapping program　USGS三维高程制图程序
UK (OSGB)	500	>20	National mapping / high-density urban　国家测绘/高点密度城市数据获取
Sweden	7184	>20	Land mapping (municipalities), forestry (University of Agriculture) at high point density　土地测绘、高点密度林业
Norway	Pilot	N/A	National Height Model　国家高程模型
Denmark (Copenhagen)	Pilot	N/A	National Height Model/ Hydro (Ministry of Energy, Utilities and Climate – Agency for Data Supply and Efficiency – SDFE) 国家高程模型（军事能源、设备及气象）
Netherlands (HWH)	Pilot	N/A	Dutch national height model　荷兰国家高程模型
Germany (BKG and Riverian Administration)	Pilot	N/A	National mapping　国土测绘
Austria (OBB Infrastructure)	Pilot	N/A	Railway mapping　铁路测绘
Austria (City of Vienna)	Pilot	N/A	High-density mapping　点密度点云测绘

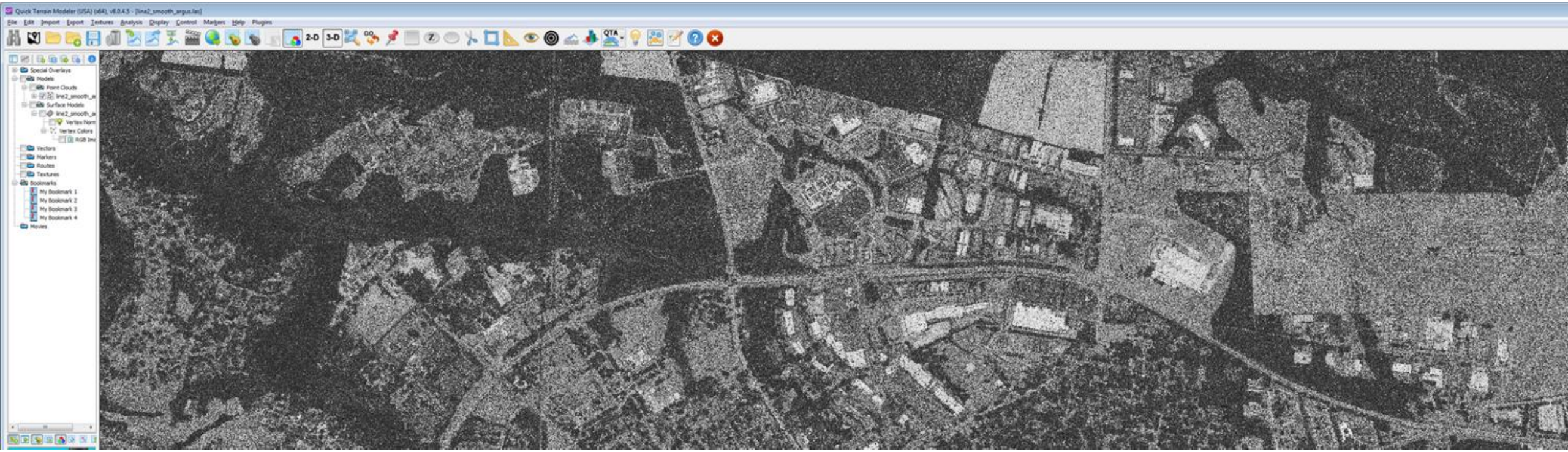
Capture & deliver dense LiDAR & Imagery
捕捉 & 实现密集的激光雷达和高清晰影像

Color by elevation
高程显示



Capture & deliver dense LiDAR & Imagery
捕捉 & 实现密集的激光雷达和高清晰影像

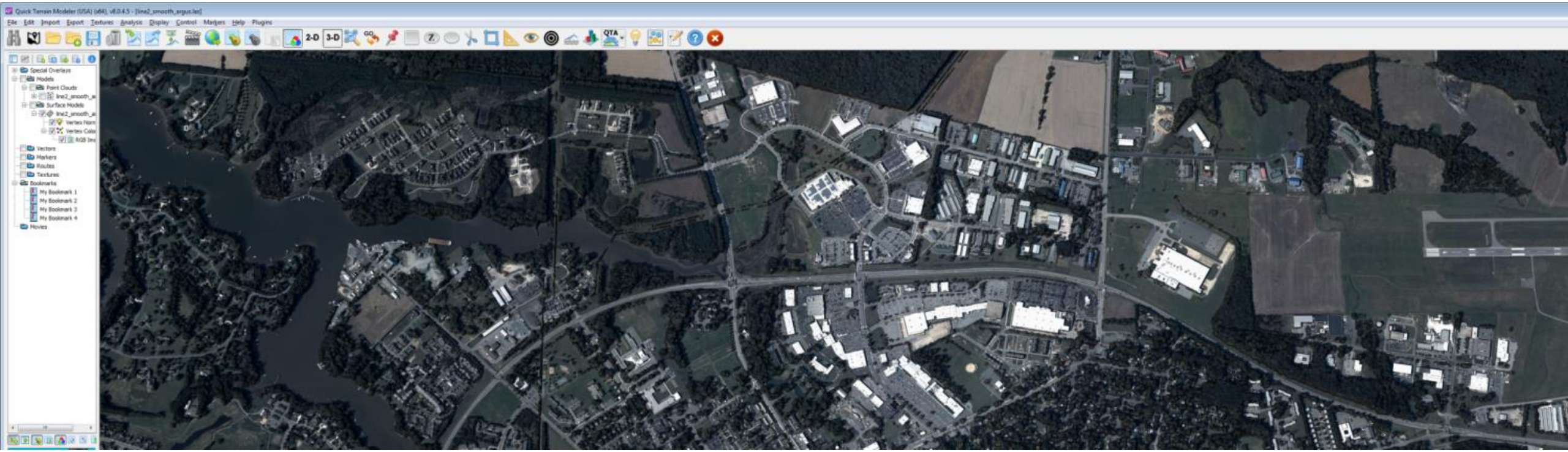
Gray-scale by intensity for enhanced classification
强度显示，增强分类



海克斯康 HEXAGON

Capture & deliver dense LiDAR & Imagery
捕捉 & 实现密集的激光雷达和高清晰影像

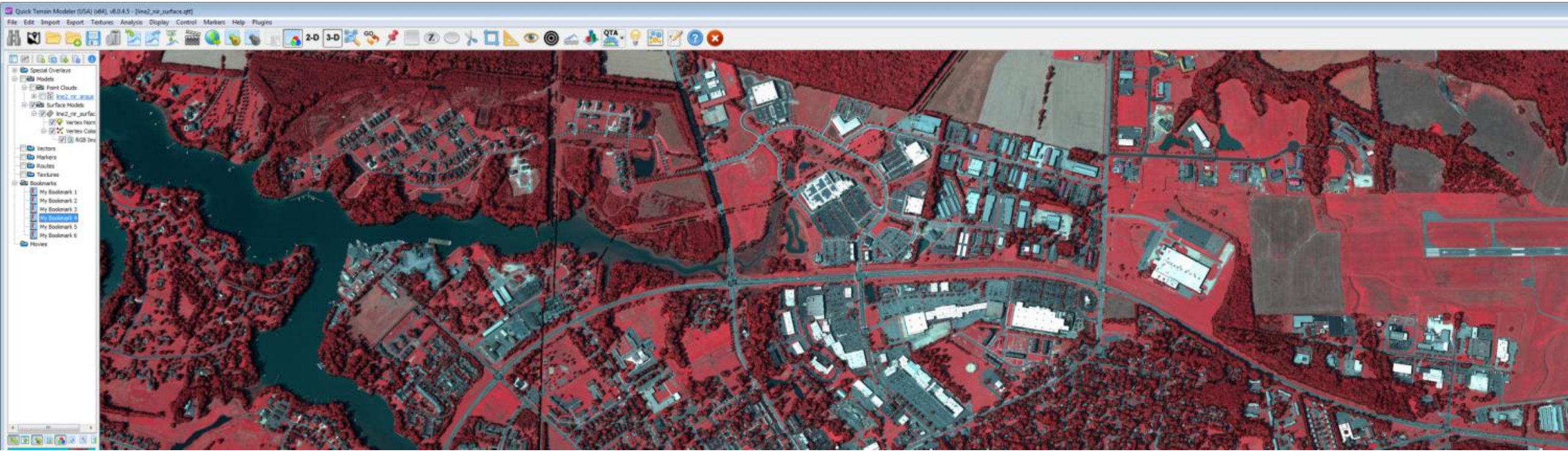
Natural color point cloud for easy object identification
点云着色，易于物体分辨



海克斯康 HEXAGON

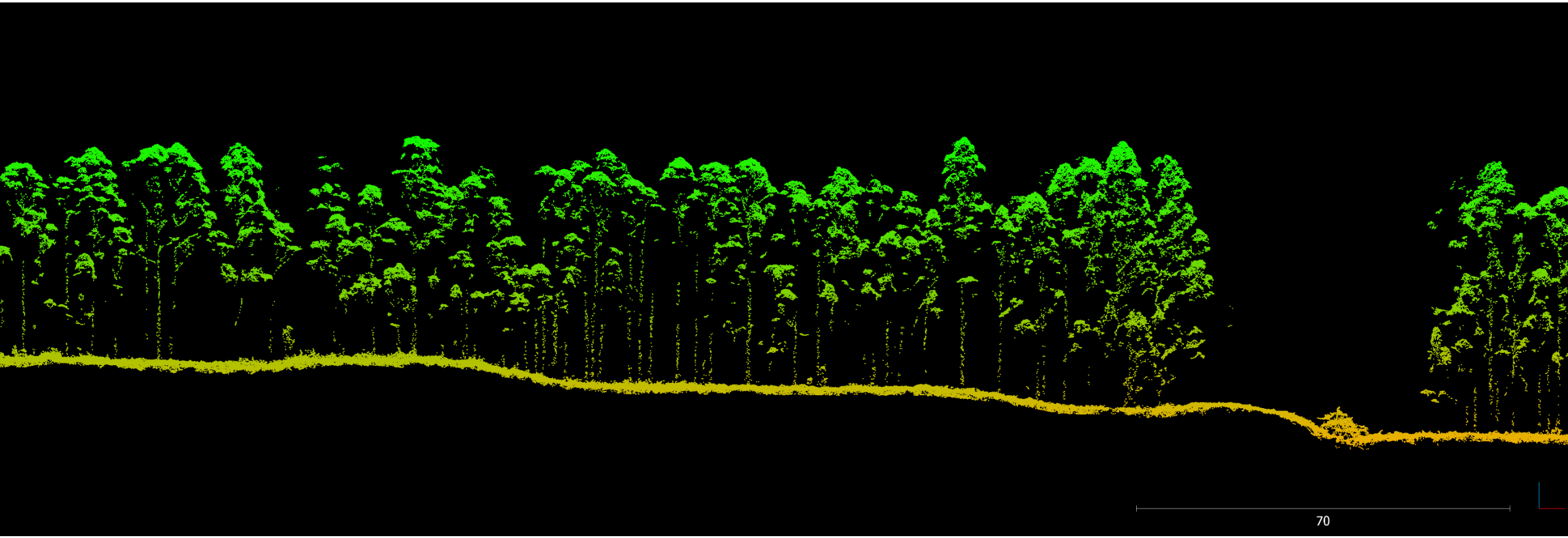
Capture & deliver dense LiDAR & Imagery
捕捉 & 实现密集的激光雷达和高清晰影像

False-color infrared for vegetation classification
加彩色用于植被分类



海克斯康 HEXAGON

Forest penetration benefits from multi-return capability and oblique scanning
森林穿透能力得益于多回波能力和倾斜扫描方式

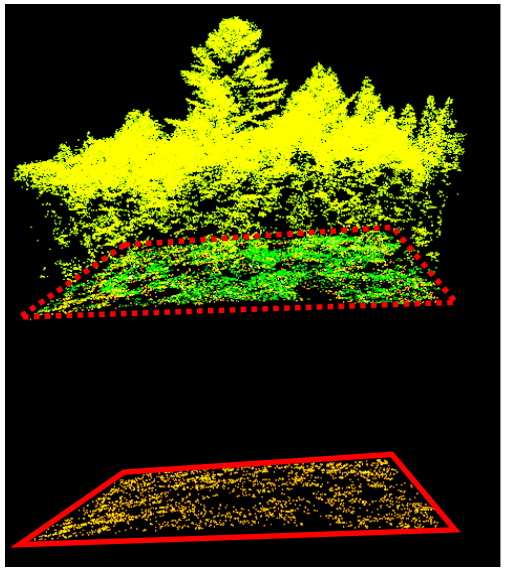


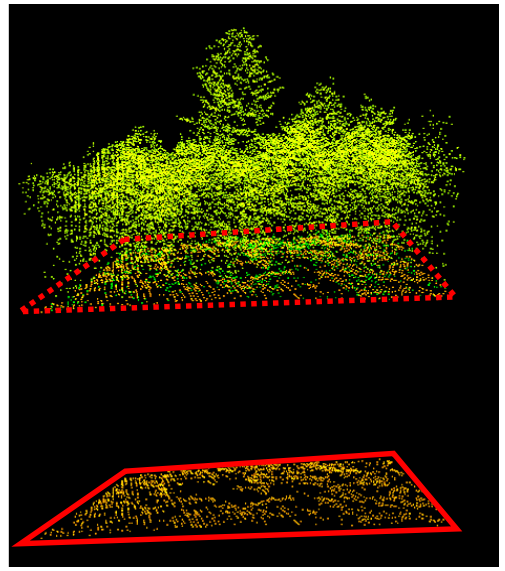
海克斯康 HEXAGON

SPL100 ground return rates similar to linear-mode LiDAR
SPL100与线性激光雷达相似的地面探测能力

- Petawawa research forest, Ontario, Canada
- Mixed species (~60% pine, 40% hardwood)
- SPL100 in 2018
  - Flying height AGL: 12,000’
  - Pulse rate: 50kHz
  - Scan rate: 20Hz
  - FOV: (30 deg FOV)
  - Speed: ~170 knots
  - Density (50% side overlap) 25/m^2
  - Ground hits this area: 2983 points
- ALS in 2012
  - Point density: 15/m^2
  - Ground hits this area: 1858 points
- SPL gives 1.66x the point density on the tree crowns
- SPL gives 1.60x the point density on the forest floor

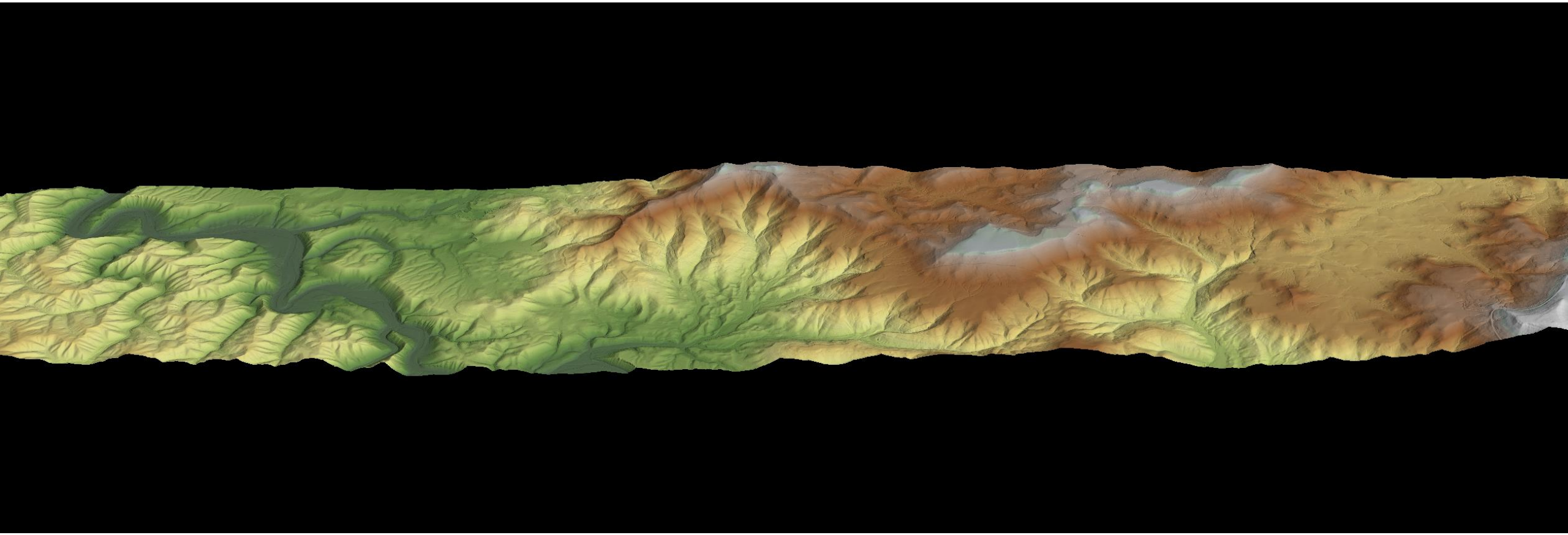
- Petawawa森林研究，安大略，加拿大
- 混合树种（~60%松树，40%硬木）
- 2018年SPL100
  - 航高: 12,000’
  - 脉冲频率: 50kHz
  - 扫描频率: 20Hz
  - 视场角: (30° FOV)
  - 航速: ~170 节
  - 点密度 (50% 重叠) 25/m^2
  - 地表点: 2983 points
- 2012年ALS
  - 点密度: 15/m^2
  - 地表点: 1858 points
- SPL100获取树冠点密度为ALS数据的1.66倍
- SPL100获取地表点密度为ALS数据的1.60倍



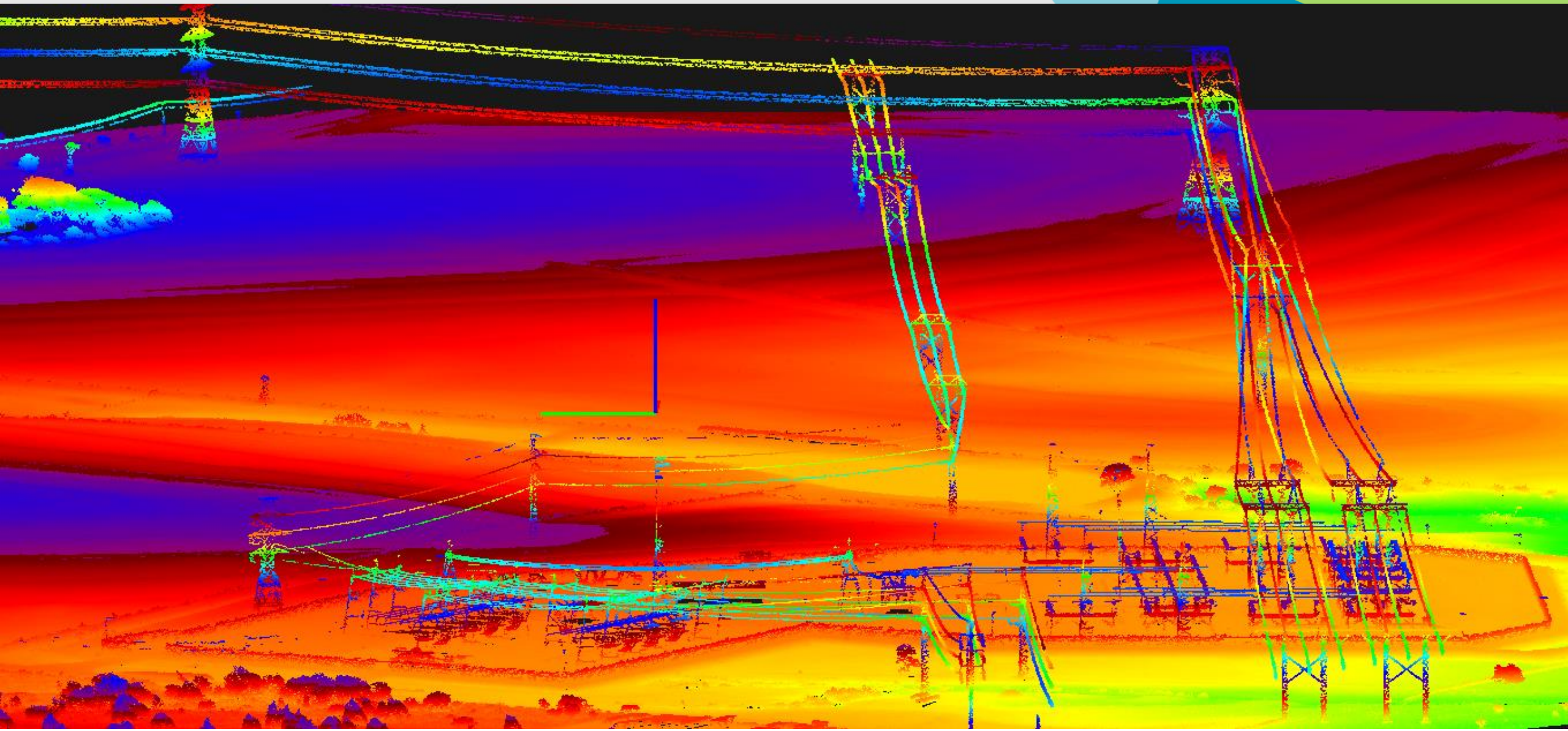


海克斯康 HEXAGON

Automatic range gate allows accommodation of large height variations
高差变化巨大的测区无需担心测距范围的限制



海克斯康 HEXAGON



Leica RealTerrain: Single Photon LiDAR (SPL) with a highly-efficient workflow
徕卡RealTerrain:单光子激光雷达(SPL)与高效率的工作流程

- Leica SPL100
- HxMap Software

Summary
总 结

- SPL100 is a proven technology for efficient large-area LiDAR data acquisition
  - Targets acquisition >30,000 km^2 for maximum efficiency
  - Readily meets USGS QL 1 specifications (8 points/m^2, 10 cm $RMSE_z$)
  - HxMap workflow provides processing power needed for 6.0M points/second data volumes
- SPL100 is suitable for a wide variety of applications
  - General-purpose mapping
  - Flood-plain mapping where tree cover interferes ability to see ground
  - Forestry application where tree details and forest penetration are important
  - Power distribution network vegetation management
- Single-photon LiDAR does not replace conventional LiDAR for some application
  - Where highest data fidelity is required

- SPL100是大面积高点云密度的积激光雷达产品
- 最大效率可采集 >30,000 的地物
- 轻松满足 USGS QL 1 规范 (8 points/m^2, 10 cm $RMSE_z$)
- HxMap 工作流为 6.0M点/秒 的数据提供了所需的处理能力

- SPL100 适用于广泛的应用领域
- 普通航测工作
- 洪泛地带的地形获取
- 林业应用中植被细节和穿透植被的能力
- 电力网络植被管理

- 在某些应用中，单光子激光雷达不能取代传统的激光雷达
- 需要保真度高的地方

谢 谢

如果您对此篇PPT感兴趣，请扫描二维码

海克斯康
HEXAGON