Airborne LiDAR
Geiger Mode vs. Traditional Linear

Mike Fuller
Geospatial Account Manager
Michael.Fuller@Harris.com
The Linear System

Technology Comparison

Linear LiDAR

- Single pulse
- Single measurement
- Low sample rate

Approximately 500KHz for single scanner designs
Limitations of existing technology

• Cost prohibitive for high resolutions

• Has inherent data occlusions

• Foliage penetration is limited

• Limited-range resolution (target separation)

• Low-sensitivity, high-power system
The Geiger-mode System

Technology Comparison

Geiger LiDAR

- Large array collection
- Collection from multiple angles
- High sample rate
  (204 million samples per second)

200MHz vs. 500KHz
Geiger-mode vs. today's technology

Geiger-mode sensors sample the same spot on the ground multiple times
Geiger-mode superior capabilities

- High-sensitivity
- Low-power system
- Higher-resolution
- More accurate data
- Large-aperture Palmer scanner
- Multi-pulse-in-the-air
- Automatic range gate control

Geiger-mode flies higher and collects faster than current sensors
Why is Geiger-mode superior?

• Improves speed of collection
• Increased data density (resolution) at lower cost
• Improves foliage penetration
• Reduces shadows/voids
• Higher accuracy with robust bundle adjustment
• Improved range resolution (separation)

Large-area, high-density collection leads to new users and opportunities
## Harris LiDAR Capability Overview

### Speed of collection metrics @ 8PPM

<table>
<thead>
<tr>
<th>8 points/m² Collection</th>
<th>Current Linear Mode</th>
<th>Flash (Linear Array)</th>
<th>Photon Counting PMT</th>
<th>Harris Geiger-mode Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude (AGL)</td>
<td>150 - 1500m</td>
<td>500-2000m</td>
<td>1000-8500m</td>
<td>4000-11000m</td>
</tr>
<tr>
<td>Field of View</td>
<td>45-60°</td>
<td>5-10°</td>
<td>10-40°</td>
<td>30°</td>
</tr>
<tr>
<td>Flight Speed</td>
<td>50-100 kn</td>
<td>200-250 kn</td>
<td>100-200kn</td>
<td>200-450kn</td>
</tr>
<tr>
<td>Laser Power</td>
<td>200-500mW</td>
<td>120-400mW</td>
<td>1-2W</td>
<td>20-40W</td>
</tr>
<tr>
<td>PDE</td>
<td>N/A</td>
<td>N/A</td>
<td>10-15%</td>
<td>25-40%</td>
</tr>
<tr>
<td>Pulse Width (Resolution)</td>
<td>1 - 10 ns</td>
<td>5 - 10 ns</td>
<td>700-900ps</td>
<td>300-600ps</td>
</tr>
<tr>
<td>Timing Jitter (Precision)</td>
<td>50-500ps</td>
<td>50-500ps</td>
<td>50-100ps</td>
<td>250-500ps</td>
</tr>
<tr>
<td>Pulse Repetition Frequency</td>
<td>100 - 800kHz</td>
<td>20-30Hz</td>
<td>20-35kHz</td>
<td>50-90kHz</td>
</tr>
<tr>
<td>Detector Count</td>
<td>less than 10</td>
<td>16k</td>
<td>100</td>
<td>4096</td>
</tr>
<tr>
<td>Ground Samples/Second</td>
<td>100k-800k</td>
<td>325k-500k</td>
<td>200-350k</td>
<td>200M-400M</td>
</tr>
<tr>
<td>Return Surface(s)</td>
<td>1,4,Full Waveform</td>
<td>1, Multiple</td>
<td>Multiple</td>
<td>Multiple</td>
</tr>
<tr>
<td>Area Coverage Rate (w/desired overlap)</td>
<td>50-180km²/hour</td>
<td>40-160km²/hour</td>
<td>170-500km²/hour</td>
<td>1000-1600 km²/hour</td>
</tr>
<tr>
<td>Operational Maturity</td>
<td>20-25 years of airborne operation; Evolutionary Improvements</td>
<td>Limited operations in airborne mapping; Technology undergoing incremental improvement</td>
<td>&lt; 5 years in experimental mapping operations; Emerging technology undergoing rapid improvement</td>
<td>5-10 years in defense operations mapping hundreds of thousands of km²; Over 15 years in experimental use; Emerging technology undergoing rapid improvement</td>
</tr>
</tbody>
</table>

Geiger-mode sensors can collect 5x, 10x, etc. with increased density.
Reduced Cost at Higher Resolutions

Efficiency gains keep costs down at higher collection densities

Collection Cost

Collection Density (points per square meter)

Current Systems

IntelliEarth™ Geospatial Solutions Geiger-mode
**Superior Performance**

<table>
<thead>
<tr>
<th></th>
<th>Linear LiDAR</th>
<th>Geiger LiDAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (points per meter)</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Instantaneous Coverage Rate (mi²/hr)</td>
<td>50</td>
<td>850</td>
</tr>
<tr>
<td>RMSEz (cm)</td>
<td>9.25</td>
<td>9.25</td>
</tr>
<tr>
<td>Altitude (AGL ft)</td>
<td>3,200</td>
<td>27,000</td>
</tr>
<tr>
<td>Swath Width (ft)</td>
<td>3,300</td>
<td>16,000</td>
</tr>
<tr>
<td>Ground Speed (kts)</td>
<td>90</td>
<td>290</td>
</tr>
</tbody>
</table>

Higher the density greater the payback
Why do higher densities matter?

Infrastructure details better defined

- Improves foliage penetration to better sample bare earth
- Improves accuracy and enables a high level of automation
Why oversampling and 360° look matters

Shadows (occlusions) from linear scanners
Why oversampling and 360° look matters

Vegetation Shadows (occlusions) from linear scanners
Eliminates the accordion effect

Accordion effect from linear
Solution 360° look and oversampling

Multi-angle Illumination

- Improves foliage penetration
- Removes shadows
- Eliminates voids
How to improve accuracy?

Aggregating data requires accurate swath alignment

Utilize latest INS/GPS

Utilize horizontal and vertical ground control points

50% overlap swaths

Perform bundle adjustment via data tie points correcting both horizontal and vertical alignment from multiple look angles.

Note: (This is both sensor and process specific)

True photogrammetric bundle adjustment to provide higher accuracy
Accuracy improves with rigorous bundle adjustment

Multi-Swath Alignment via Sensor-Based 3D Photogrammetric Bundle Adjustment

Enables Rigorous Accuracy Statements per Point

Sensor Position and Attitude Covariance at Multiple Times

Adjusted Sensor Position @ Time=t

Adjusted Sensor Trajectory

Point Cloud Data

LOS to Point

3D point uncertainties

3D point

Sensor-based adjustment enables per point accuracy statements
What to do with all this data?

- Not for the workstation in raw form
- Terabytes to petabytes in data management and processing
- Requires high-speed, distributed, multi-core processing
- System has been highly evolved over 15 years
- Sorties are processed in <24 hours
- Total solution requires innovations in both hardware and software
Automated GmAPD LiDAR Processing…

Ground Processing Workflow

Point Cloud Processing

- Preprocessing & Calibration
- Sensor
  - ToF Data
  - Pointing Data
  - GPS/INS Data
  - Flight Logs
- Control
  - Ground Survey
- Ingest & Project Setup
- Data Management & Archive

Data Finishing

- Noise Filter Single Swaths
- Match Point Filter
- Noise Filter Cross Swath Aggregate
- Manual Registration Aggregate Chips to Ground Survey
- Sensor Based Swath Registration
- Point Cloud Generation
- Point Cloud Auto Classification
- Hydro Enforcement Clean Up QC Analysis
- Batch Gridding, Re-Tile & Format
- QC Products
  - GeoTIFF & PNG
    - Anomaly Mask
    - Interpretation Mask
    - Height Map
- QC Products
  - GeoTIFF
    - L4 Intensity Image (RII)
    - L4 Reflective Surface (DSM)
    - L4 Bare Earth Surface (DTM)
- Point Cloud Products
  - Attributed LAS
    - L4 Point Cloud (PC3)

Increased ground automation is critical for reducing production costs
Geiger-mode is the key to reduced cost and higher quality data

Geiger-mode Sensors to Increase Acquisition Rates
- Higher Altitudes
- Wider Swaths
- Lower Laser Power
- Higher Density
- Decreased Shadowing

Automated Production to Reduce Hands-on Analyst Time
- Large Areas
- LiDAR Production Management
- Point Classification
- Value-Added Products

Improved Registration and Quality Control for Accurate Products
- Automated QA/QC
- Swath Alignment via Bundle Adjustment
- Integrated Ground Control Locking

Built on Harris’ 15 year Geiger-mode production legacy
IntelliEarth™ Geospatial Solutions
Geiger-mode (GmAPD) LiDAR sensor

Built specifically for wide-area, high-density collection
Examples

Proven workflows have produced hundreds of thousands of kilometers of high-quality data.
Applications

Exploration & Production
- Seismic Survey Planning
- Seismic Processing
- Well Site Planning
- Logistics
- Design & Construction

Pipeline
- HCA and Class Location Analysis
- Right of Way Encroachment
- Overland Spill Modeling
- Design & Cost Estimates
- Route Planning
Questions?

Mike Fuller
Geospatial Account Manager
Michael.Fuller@Harris.com
321.984.5699