From Diesel/Iron to Avgas/Knowledge in 42 Years
Serving Central Canada’s Northland “Practical Innovation”
KBM Services

- Digital Aerial Photography
- Geospatial Services
- First Nations Relations
- Consulting Services
  - Land Use Planning
  - Environmental
  - Permitting
- Field Work
- Field Supplies
Digital Aerial Photography – Image Acquisition

- True-colour, 4 band, Thermal IR, high-resolution image capture (3 - 40 cm) with inertial navigation systems
- LiDAR Harrier 68i
- 5 dedicated long-range aircraft and experienced crews since 2004
- Fixed Wing UAV
Willingness vs Ability to Pay

Applications – North America
Utilities Mapping 20K km
LiDAR/AP – Data Capture, Processing and Analysis

Raw Data Processing

- GPS and inertial data to trajectory - POSPac
- Aerial triangulation and orthorectification of imagery – Trimble INPHO suite
- Raw LiDAR processing, waveform to discrete echo – Reigl RiAnalyze
LiDAR/AP – Processing and Analysis

Analysis

- Softcopy photo interpretation – DAT/EM Summit Evolution and ArcGIS Desktop
- LiDAR classification – SCOP++
- Point cloud editing – MARS
- Feature coding and extraction: TerraScan
- DEM and Contour generation – ArcGIS desktop
Workflow and Resources – Data Delivery

Data integration:
- Consolidate and relate datasets – ArcGIS Desktop
  - Ortho imagery
  - Oblique imagery
- Photo interpreted vector and tabular data
- Contours
- LiDAR derived features
Workflow and Resources – Data Delivery

Web delivery:

- Create online GIS viewer in a hosted environment
  - ArcGIS 10.2 Server
  - ArcSDE – SQL Express Database
  - Geocortex Essentials Silverlight Viewer
Workflow and Resources – Data Delivery

- Secured access to data
- Web delivery:
  - https://insight.kbmrg.ca
  - Publish data to web viewer
Walrus Surveys
Mining

- Digital 3D and traditional mapping
  - Land cover classification, feature mapping
- Digital terrain modelling & stockpile inventory
  - Elevation, contours, cut/fill, volumes
  - Hydrology
- ArcGIS server hosting services
The Forest Sector

Applications – North America

- Forestry Mapping
- Coast and Disaster Management Mapping
- Urban Mapping
- Mining Area Mapping
- Highways and Roads Mapping
- Power Lines and Pipelines Advanced Monitoring
- Power Lines Mapping
- Pipelines Mapping
- Detailed Engineering Applications
- Wide Area Mapping
2008 Pilot Project with Resolute ID Within Block Variability

- Plot 14 (top)
  - ~ 200 m³/ha
  - 12 and 16 cm Sb
- Plot 7 (bottom)
  - 270 m³/ha
  - 28 and 32 cm Pj
Recommended 1:10,000 Photo Mosaic Operations Planning Base
Proposed Digital/GPS Harvesting System

- SK-Blue GPS receiver 30-60 cm (1-2 feet) accuracy in realtime
- On-screen display in harvesters of current location, harvest boundaries, AOCs, Mosaic backdrop etc
- Harvesting locations tracked and uploaded to company GIS

Each harvester is equipped with a GPS recorder that tracks location and activity.

Harvest boundaries are defined as digital shapefiles and downloaded to the computer on the harvesters. This enables them to see where they need to cut and track where they have already been.
Cutover Mapping & FTG Surveys

- 1.5 mm ha cutover map
- 350 k ha FTG surveys
Stocked plots 1930s; for describing forests too young to detect using remote sensing (aerial mapping).
- ABI CON $45k/yr 20 years SRF> Binder Heaven; just like Laird’s reports

Canada has always relied on remote sensing for forest inventory vs more statistically sound methods deployed in the US and Europe

We make near term costly decisions based upon FRI $0.50/m3
- ($10m/yr/AAC 20m m3)
  - $1.5-1.8/gross ha every ten years is $0.15-0.18/ha/yr

Invest in total SEM $0.12/m3
- SFL $1M/yr ($5/ha) and MNR $1M/yr for a 10% sample and IFA $0.5/yr for a 10% sample> $2.5M/yr ) or
  - $0.045/ha/yr

A negotiated position based upon Crown Ownership and Concessions
FTG Moving Forward

- Coarse height classification modelling.
FTG Moving Forward

- Vertical Point Sample Methodology
- SGR FTG HT of 1 meter
- Use a 1 m radius in a circular plot. All trees taller than 1 meter are tallied, all trees taller than 2 meters are tallied in a 2 meter radius and so on.
- Like FRI Probability Proportional to Size (PPS)
- photo inter calibration of same methods for ground plots and photo plots
- Since we are not counting small trees can use 15cm photos and reduce costs to target $5/ha same as heli aerial observation.
Enhanced FRI (eFRI)

- 2005-2009: medium resolution (35 cm) multispectral digital imagery (ADS40).
- 10-year FRI cycle
- Significant advance over the previous standard of 1:20,000 panchromatic black and white photography
- Soils and landforms also considered during ecosite classification
- Direct data entry into a GIS
- Enhanced estimation of canopy height
- Semiautomatic methods for volume estimation
- Enables generating terrain models for operational planning purposes
- KBM has recently used eFRI products to serve its clients' needs and found the data quite reliable in terms of describing forest values including volume by species.
- The data is more reliable than previous FRI due to enhanced image quality and ground sampling.
- The data is in a consistent format with historic FRI.
- FRI has an undeserved "bad rap".
2015 OPC 20 points/stand 24 stands

NB: volumes show good agreement due to small height of Bf
Source: KBM Lac La Criox First Nation CORDA project
MNRF training in BW hard copy till 2010
A minority of SFLs have Softcopy workstations
Softcopy stereo interpretation
The value of FRI ADS 40 data continues to diminish with time
$0.50/ha now $0.05/ha
Manual, visual photo interpretation of stand stocking and basal area is subjective.

Can we automate it with statistical models and digital imagery?
- Yes. Our models show good match to field data.
Field Sampling BA
Stocking
Basal Area

![Graph showing Basal Area](chart.png)

- **Method**
  - Field
  - Model_Combined
  - Model_ITC
  - Model_TEX

- **ForestType**
  - ConMx
  - PoDee
  - SbLow

- **Stand Basal Area (m²/ha)**
  - Range from 10 to 40

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**Legend**
- Orange: Field
- Grey: Model_Combined
- Green: Model_ITC
- Red: Model_TEX
Digital data allows for automated classification

(adapted from Boucher et al. 2003, Nguyen 2002)
MW2 & SF1 Results

PCA 1 (37%)

-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

PCA 2 (31%)

-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

DTOT  Dlpct  Dmpct  Dspct  Skew  CV  S  H  E  rangedbh  maxdbhc  w_scale  w_shape  CCR  CCH  CCE

Cohort III
Cohort II
Cohort I

MWSF MEAN WEIBULL CURVES

DBH (cm)

0 20 40 60

Tree density (%)

0
5
10
15
20
25

Class 1  Class 2  Class 3

a) Mixedwood

Fire (Clear-cutting)

1st cohort  2nd cohort  3rd cohort
Current system has significant *workflow* issues:

- Only 8 million ha out of 55 million ha completed
- Large number of FMPs will be based on 15 year old data
- Large fluctuations in flows of cash, technology and human resources
- Large number of temporary photo-interpreters = large unsystematic bias in data
Continuous FRI (cFRI): Concept

cFRI – an alternative approach to eFRI on a 10-year cycle with an annual workflow schedule

- Exactly the same information as eFRI
- Equivalent or lower costs with better cash flows/workflows
- Logistics advantages by combining:
  - annual FRI updates of cutovers
  - semi-annual updates of FTG
  - AND updates of adjacent mature forest cover
- Operating areas can be targeted with advanced imagery (ALS, LSP) for a value added proposition.
NFMC Case Study

- **Integrated annual image acquisition scheduling**
  - Tile based system (OBM 10 by 10 km tiles)
  - Tile Mission Schedule based on KBM SAP Acquisition (2003 – 2012)

<table>
<thead>
<tr>
<th>Period</th>
<th>New Tiles Captured</th>
<th>Tiles Previously Captured</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>102</td>
<td></td>
</tr>
</tbody>
</table>

**Approach:** *Unbalanced Data Capture Sequence*
- Schedule tiles based on planned FRI maintenance tasks

**Summary:**
- **102 of 142 tiles** captured
- **Out of 102 tiles, several tiles re-captured** two or more times to update new disturbances
- **40 tiles** left for updating to match 10-year cycle
- Variable annual FRI update schedule

Nawiinginokiima FMC
**NFMC Case Study: Summary**

### Proposed cFRI funding scheme for NFMC:

- **NFMC**
  - Use $200,000 for LIDAR and/or operations data
  - 10-12% contribution to parks and protected areas

- **MNRF**
  - 10% of contributions for their QC
  - Contributions to the cFRI?

<table>
<thead>
<tr>
<th>Current FRI contributions</th>
<th>cFRI estimated cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$700,000 - 900,000/yr (Source NFMC)</td>
<td>$320,000 /yr</td>
</tr>
<tr>
<td>$0.53/m³ for image and production costs to $1.00/m³ total system costs (source MNRF)</td>
<td>$0.36/m³</td>
</tr>
<tr>
<td>$1.50-$1.65/ha (source MNRF)</td>
<td>$1.60/ha but focused on areas of interest</td>
</tr>
</tbody>
</table>
## cFRI and eFRI

<table>
<thead>
<tr>
<th>eFRI</th>
<th>cFRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIM compliant forest wide</td>
<td>FIM compliant 20 tiles/year</td>
</tr>
<tr>
<td>Ten year cycle of image acquisition</td>
<td>Annual cycle of image acquisition</td>
</tr>
<tr>
<td>• 4 band 40 cm stereo</td>
<td>• 4 band 40 cm stereo</td>
</tr>
<tr>
<td>• TBD for next cycle but still locked in technology for ten years</td>
<td>• Technology is changing in shorter than ten year cycles (&lt;5 years)</td>
</tr>
<tr>
<td>Ten interpreters over 3 years</td>
<td>Two interpreters continuous cycle</td>
</tr>
<tr>
<td>Cutover, Natural Disturbance and FTG updates</td>
<td>Disturbances and FTG updates enjoy potential economies of scale and logistic advantages</td>
</tr>
<tr>
<td>extra costs and stand alone missions</td>
<td></td>
</tr>
</tbody>
</table>
Continuous FRI: Advantages

- Reduced cost by combining image acquisition missions
  - Data collection timed to coincide with optimum weather windows

- Accurate and up to date information:
  - FRI updates performed on a semi-annual or annual basis for stands that appear to have changed within unplanned (i.e. adjacent) areas

- Flexible
  - Annual image acquisition missions can be modified to capture areas deemed to have changed through satellite or other means of change detection (e.g. forest fire, ice damage)

- Consistency
  - Use of dedicated full-time photo-interpreters (2 py/SFL) who become familiar with the local forest

- Continuous improvement
  - Positive and tight feed-back mechanism between forest manager and cFRI technicians
  - Seamless integration of technology advances that happen faster than ten year cycles.
Trimble 68i
Project: Area Based Lidar Inventory Wagner Blocks (API Freehold)

- **Best Model Assessment:**
  - Sparse Bayesian regression
  - K Most Similar Neighbor (kMSN)

- Goodness-of-fit of the model is tested at the plot level by leave-one-out cross-validation method

- Independent validation data can be used when available

- Being applied to a 200,000 ha forest near Thunder Bay, Ontario

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Example inventory model

Source: Arbonaut (http://www.arbonaut.com)

Method description, statistics and quality control reporting

<table>
<thead>
<tr>
<th>Source</th>
<th>Arbonaut (<a href="http://www.arbonaut.com">http://www.arbonaut.com</a>)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory modeling</td>
<td>Arbonaut’s Forest Inventory Tool: ArboLiDAR</td>
</tr>
</tbody>
</table>

*Imagenes y gráficos proporcionados por el propio documento.*
IRAP/ Wagner Project: Individual Tree Inventory (ITC)
Wood Quality Predicted from Crown Symmetry/metrics LU

- Boreal Forest ITC Inventory Model
  - Northwestern Ontario
  - Saskatchewan

- General procedure:
  - LiDAR data processing
  - ITC delineation
  - ITC Species identification
  - Tree level attributes
  - Stand level attributes

### Tree Level Attributes

- **Species**
  - **BA Tree**
    \[ \text{BA Tree} = \pi \times \left( \frac{\text{DBH}^2}{2} \right) \]
  - **Vol Tree**
    \[ \text{Vol Tree} = \frac{\text{DBH}^2}{\frac{b+c}{HT}} \]
  - **Crown Area**
    \[ \text{Crown Area} = \text{Area (ITC)} \]

### Stand Level Attributes

- **BA per ha**
- **Volume per ha**
- **Height Distribution**
- **DBH Distribution**
- **Crown Size Distribution**
- **Top Height**
- **Top Average Height**
- **QM DBH**
- **Crown Closure**
- **Stand Density Per Ha**
Future Custom Use of Multi Phase/Scale Data WRT 4th Dimension (CFS/NWT)

http://www.carbomap.com/