David Harding
NASA's Goddard Space Flight Center
david.j.harding@nasa.gov

Overview of NASA Airborne and Satellite Laser Altimeters and Commercial Analysis Software

UNAVCO Science Workshop
Special Interest Group Session
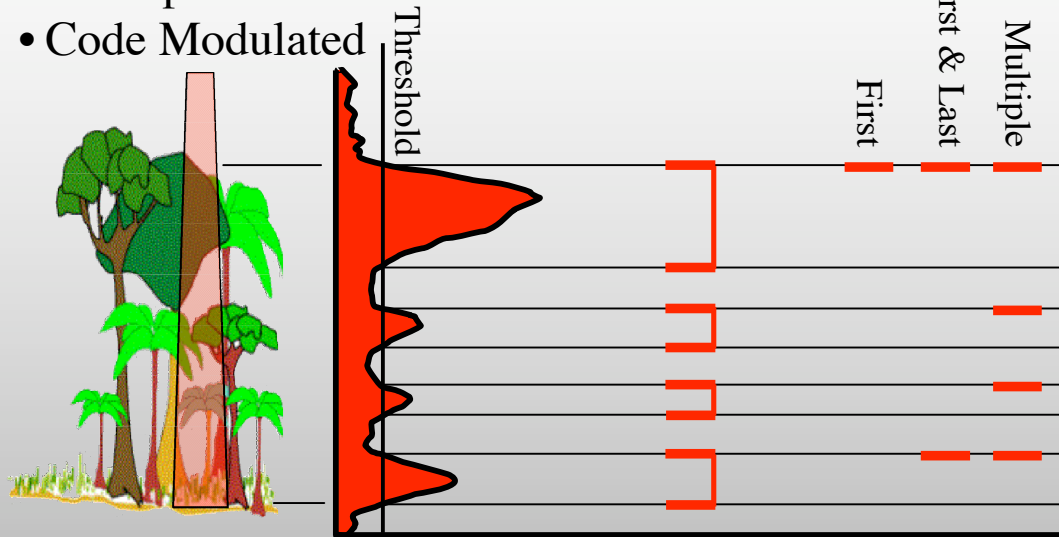**LiDAR Data: Management, Processing, and Access**

Denver, CO
March 14, 2006

Laser Altimetry Measurement Approaches

Laser Pulse:
- **Monopulse**
- Micropulse
- Code Modulated

Surface Reflectance Properties:
- **Intensity**, Depolarization
- **Single**, dual, or multi-wavelength

Cross-track Coverage:
- **Mechano-optical scanner**
- Electro-optical scanner
- Diffractive optic element
- Multi-laser pushbroom
- Segmented detector
- Combination of methods

Threshold

First

First & Last

Multiple

Detection Methods: Digitized Waveform | Pulse-Width | **Discrete Return** | Photon Counting

Point Clouds

Instruments:

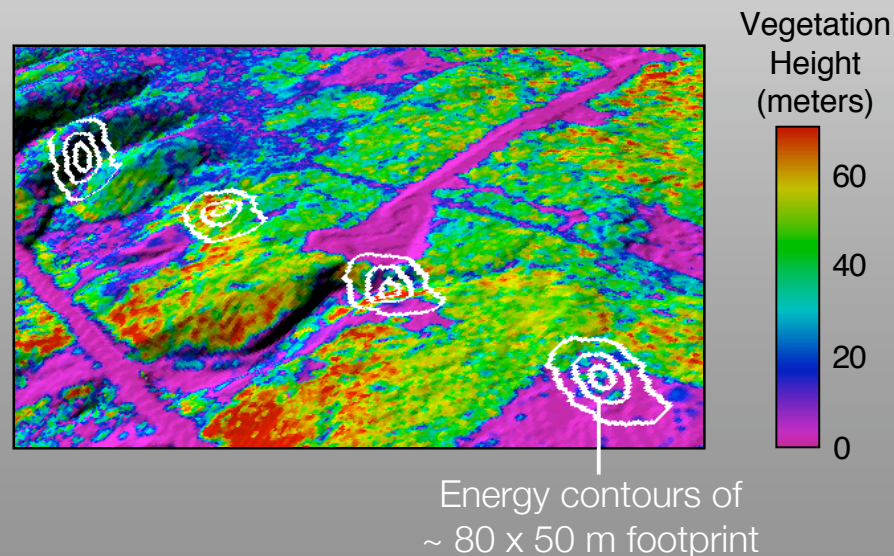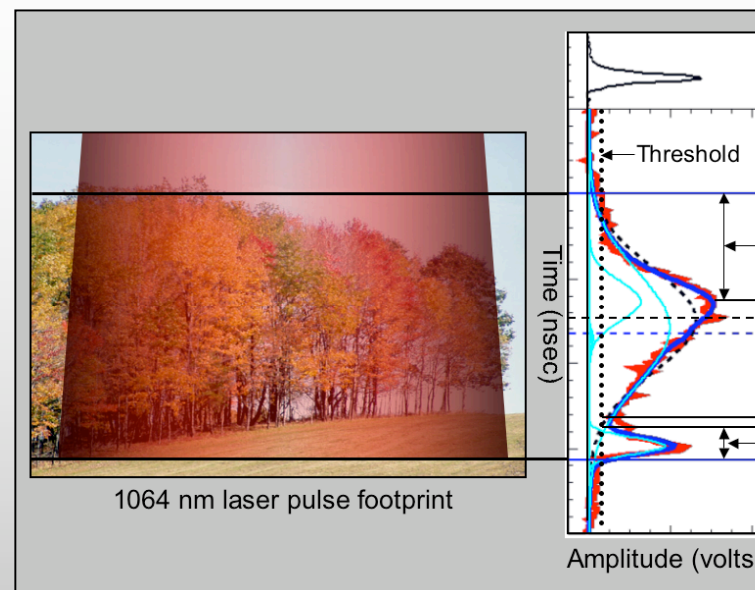|	Footprint (m)				
SLA	100	MOLA			
SLICER	10	Mars			
LVIS	5 to 30	MLA	ATM	MMLA	Systems developed at NASA's
EAARL	0.2	Mercury	**Commercial**	SILA	Goddard Space Flight Center
GLAS	70	LOLA	**Systems**	CATS	
Optech	0.3 to 2	Lunar			
Reigl	0.5				

Sources of Waveform Data: ICESAT

Mission:
Ice, Cloud and land Elevation Satellite

Instrument:
Geoscience Laser Altimeter System (GLAS)

Source:
http://nsidc.org/daac/icesat

1064 nm laser pulse footprint

Threshold

Time (nsec)

Amplitude (volts)

Vegetation Height (meters)

60

40

20

0

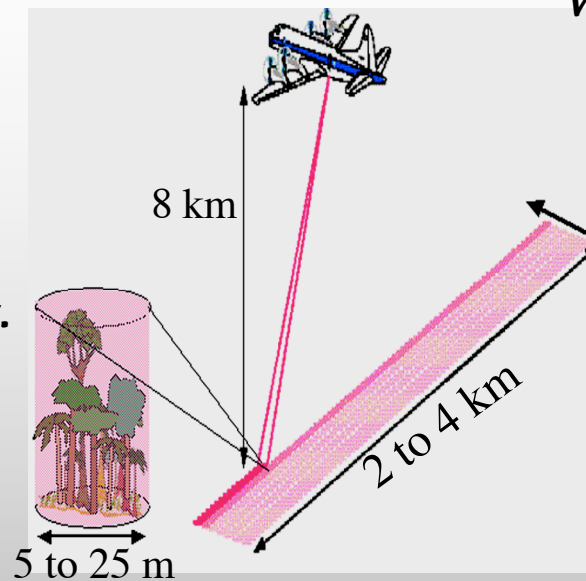Energy contours of ~ 80 x 50 m footprint
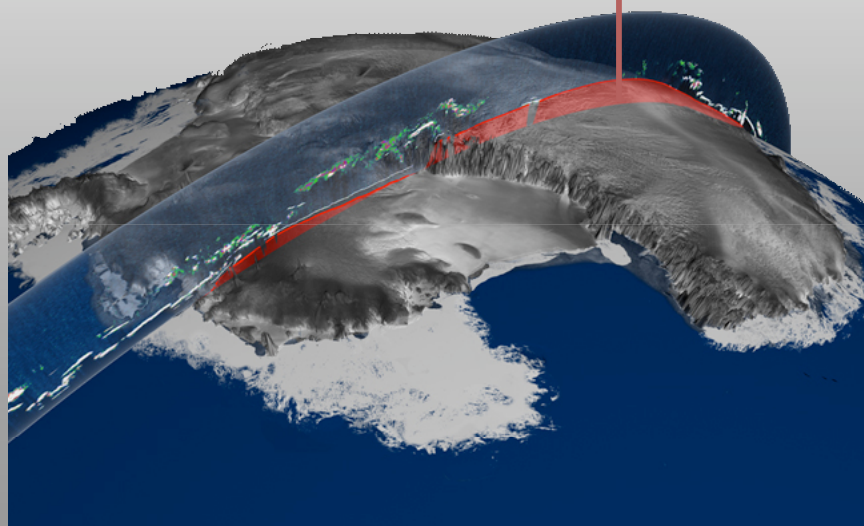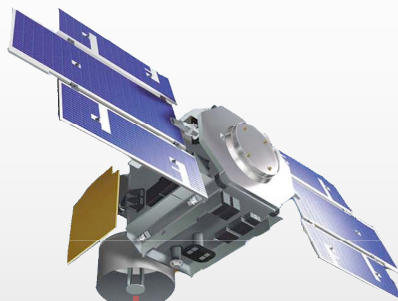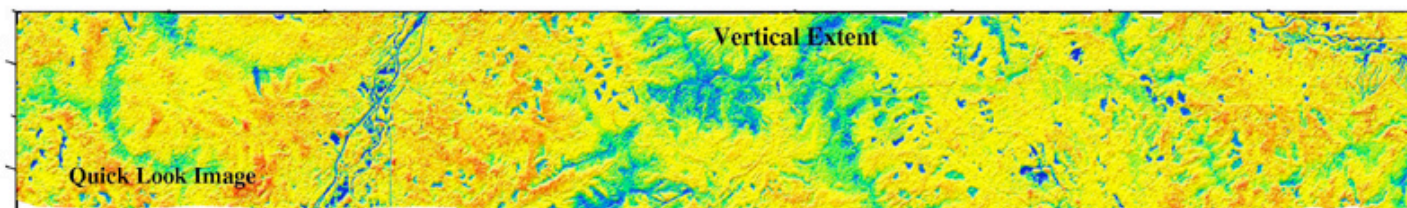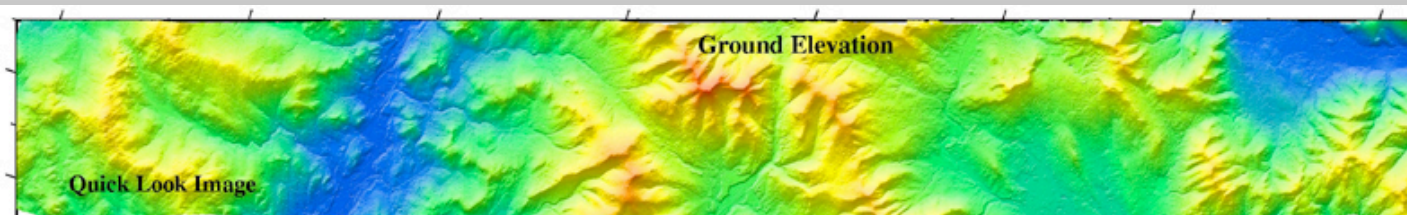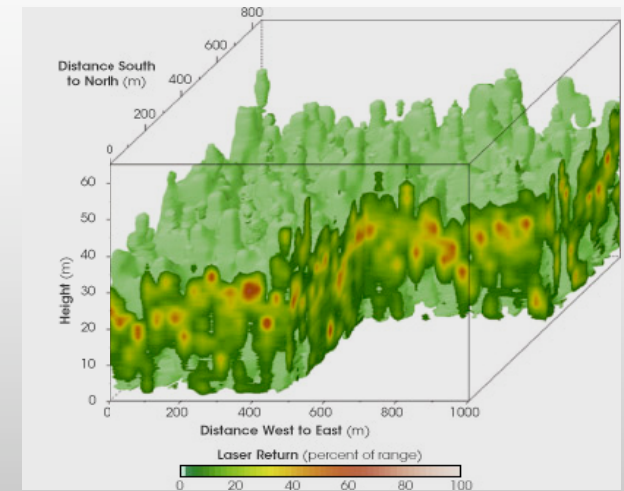
Sources of Waveform Data: LVIS

Instrument:
Laser Vegetation Imaging Sensor

Principal Investigator:
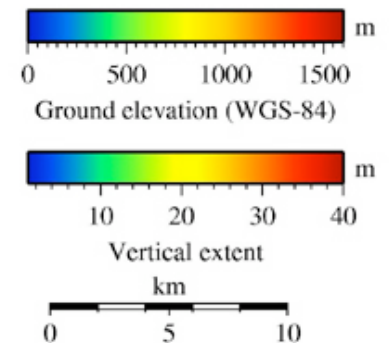J. Bryan Blair
NASA Goddard Space Fl. Cnt.

Source:
http://lvis.gsfc.nasa.gov

8 km

2 to 4 km

5 to 25 m

Vegetated Landscape Volumetric Imaging
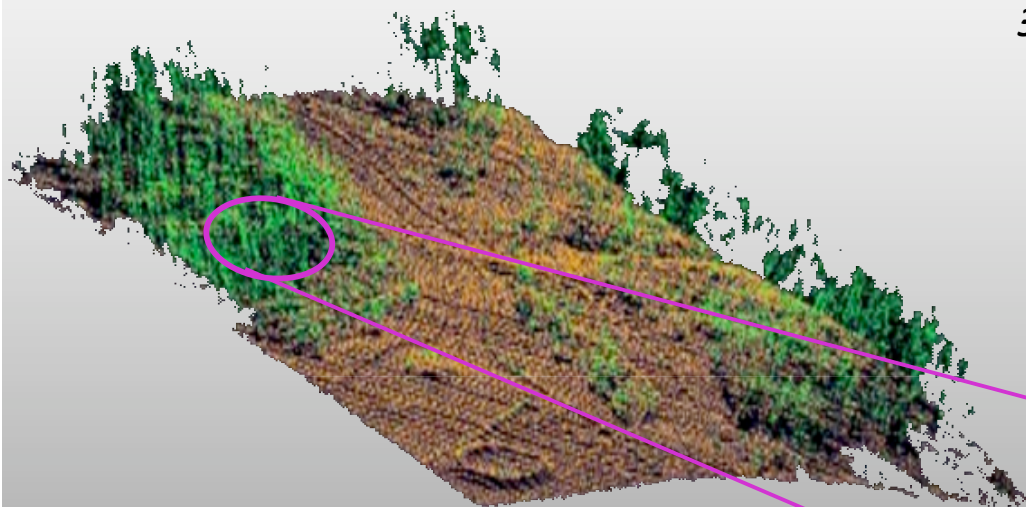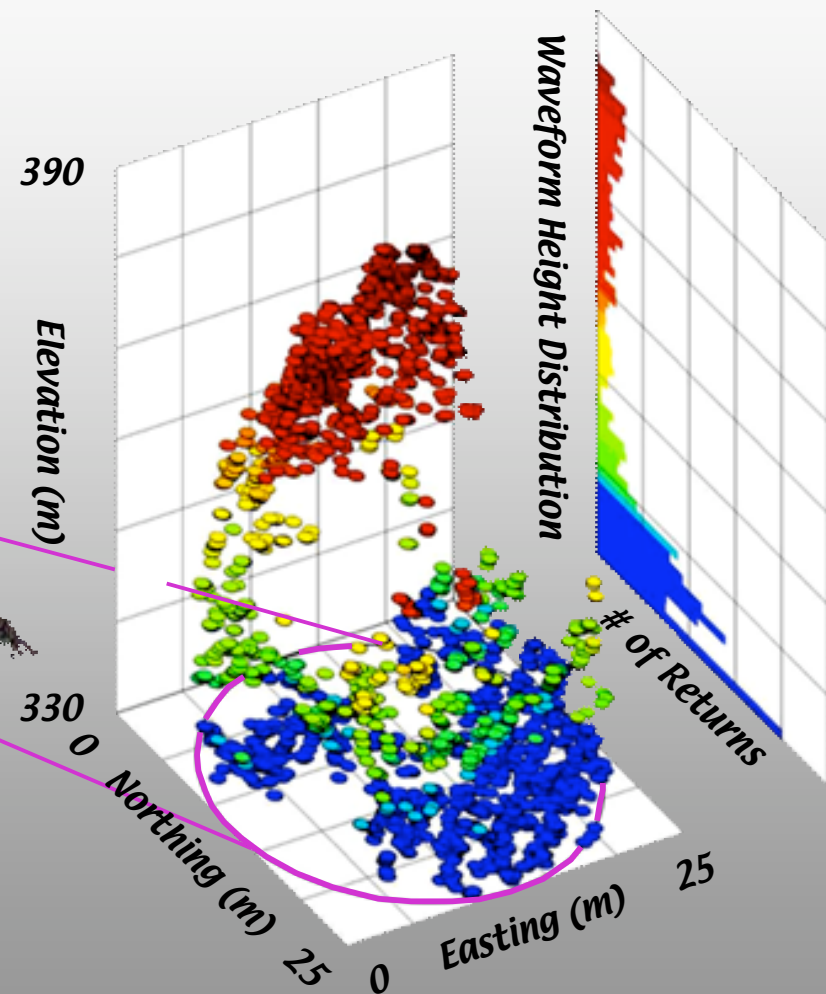*"Forest CAT Scan"*

Bartlett Forest, NH

Waveform from Accumulated Discrete Returns

Discrete returns in 25 m diameter footprint

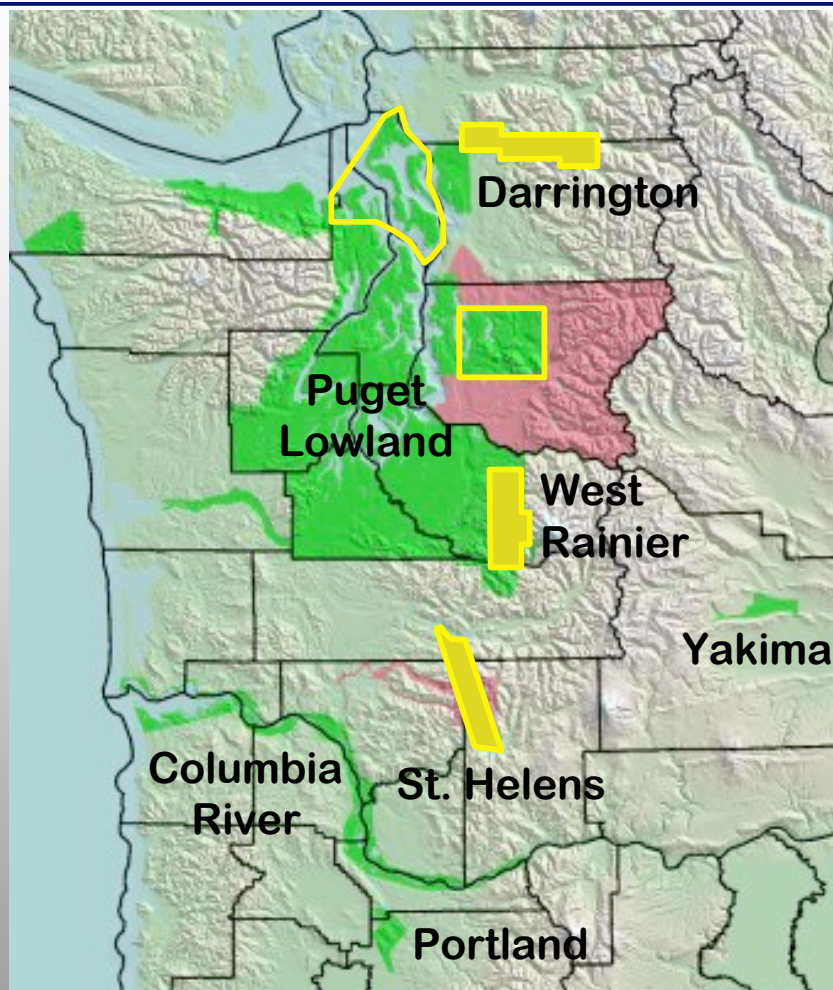**Classified discrete return point cloud**

Waveform Height Distribution

Elevation (m)

390

330

# of Returns

0

Northing (m)

25

0

25

Easting (m)

Green = vegetation return

Orange = ground return

Returns color-coded by elevation

Puget Sound LiDAR Consortium (PSLC)

Puget Sound Lidar Consortium

NASA Earth Surface & Interior funding

Other public lidar surveys

Public-domain high-resolution topography

- **Airborne lidar swath mapping**
- **http://www.pugetsoundlidar.org**
- **http://core2.gsfc.nasa.gov/lidar/terrapoint**

- **Federal-local multi-agency collaboration**
  - **Local counties and municipalities**
  - **Regional transportation council**
  - **USGS and NASA**

- **Contract with TerraPoint, LLC**
  - **Competitively selected commercial vendor**
  - **2000-05 Jan-March leaf-off data acquisition**
  - **~15,000 sq km of Puget Lowland mapped**
  - **1 pulse per sq m = 15 billion laser pulses**
  - **Up to 4 discrete returns per laser pulse**
  - **Return intensity for more recent mapping**
  - **Deliverables:**

    classified point cloud (ground, canopy, buildings)

    highest surface and bald Earth DEMs (1.8 m grid)

Commercial LiDAR Data Analysis Software

Detection Methods: Digitized Waveform   Pulse-Width   **Discrete Return**   Photon Counting
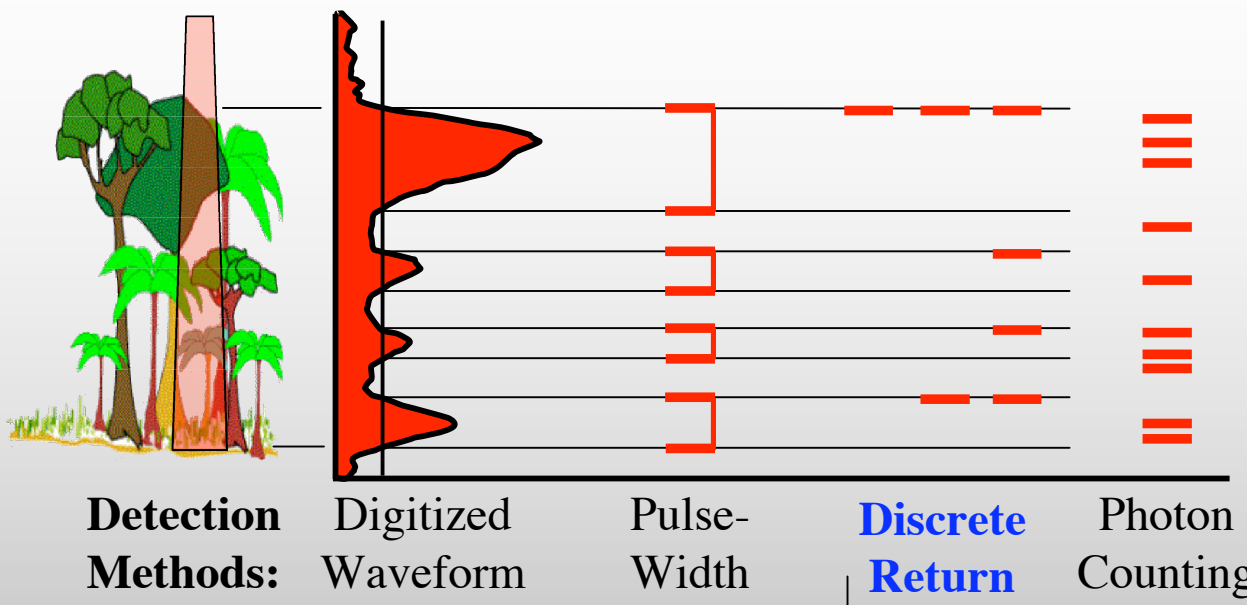
Point Clouds

IVS: Fledermaus Professional

(for bathymetric lidars)

None for land & canopy waveforms

NASA and academic R&D only, primarily developed in Interactive Data Language (IDL)

May change with Optech's & Reigl's new waveform systems

Applied Imagery: QT Modeler, Reader
InnovMetric: PolyWorks, IMView
Inpho GmbH: SCOP++, DTMaster
IVS: Fledermaus, iView3D
Pointools: Pointools View
ProLogic: LIDAR Explorer
Terrasolid: TerraScan & Modeler
Visual Learning: LIDAR Analyst
No endorsement is implied or granted

Applied Imagery's QT Modeler

DESCRIPTION:

- Process and display surface models or LiDAR point clouds of up to 200 million points

- Create surface models from point clouds

- View and navigate through 3-D models interactively, without decimating or tiling

- Four model formats: point cloud, surface model, DTED grid, vector

- Raw data ingest: ASCII XYZ, LAS, Optech Comprehensive and FLT+HDR

- Perform line-of-sight analysis, overlay images on models, measure point locations and line segments, generate contour lines, color areas by elevation, and calculate lighting and shadows

- View model statistics, save views, save and play movies in QMV format

PLATFORM: Windows 2000/XP

SYSTEM REQUIRMENTS:
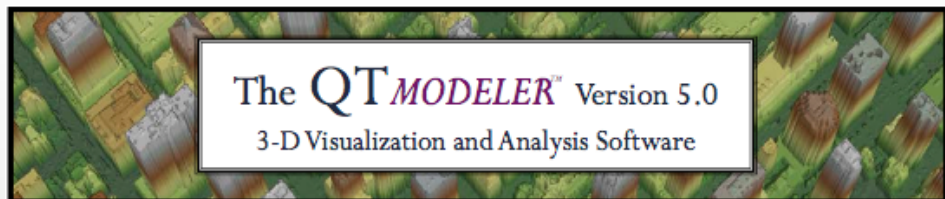An 850-MHz Pentium III with 384 MB of RAM and a 3-D graphics card that supports OpenGL

PRICE: $3,500 (software key); $4,000 (hardware key)   URL: http://www.appliedimagery.com

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

Applied Imagery's QT Modeler

The QT MODELER™ Version 5.0
3-D Visualization and Analysis Software

Optech Inc. and Applied Imagery announce partnership to deliver QT Modeler software with Optech's Airborne Laser Terrain Mapper (ALTM) systems. Jan. 23, 2006
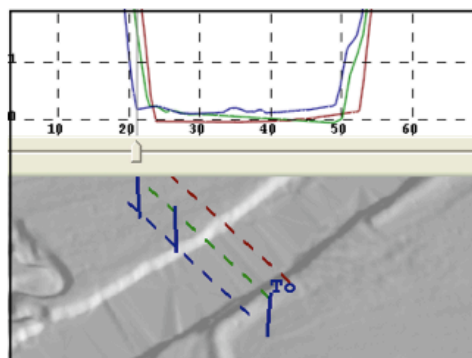
http://www.appliedimagery.com

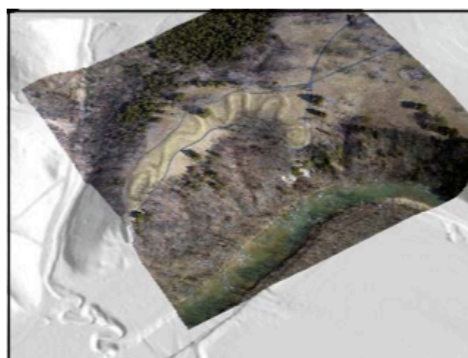Figure 1: Basic Mensuration - multiple cross sections of terrain.

Figure 2: Overlay of aerial photograph on gridded surface model.
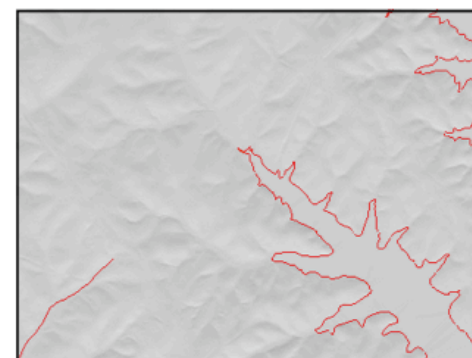

Figure 3: Overlay of shape files on the DEM. These shape files delineate flood plains and streams.
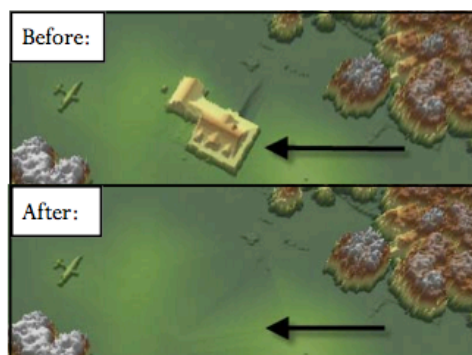
Figure 4: DEM Editing - Removing a house from the DEM with the area smoothing tool.
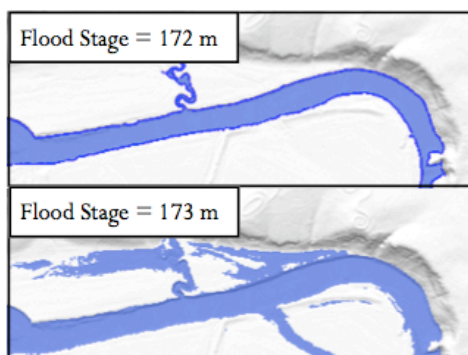

Flood Stage = 172 m

Flood Stage = 173 m

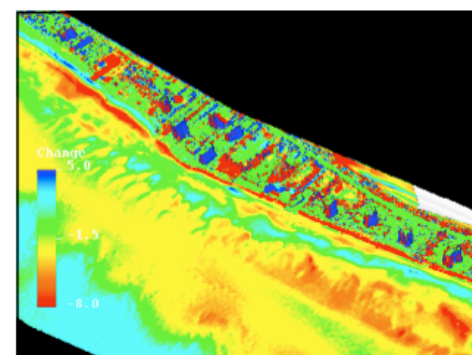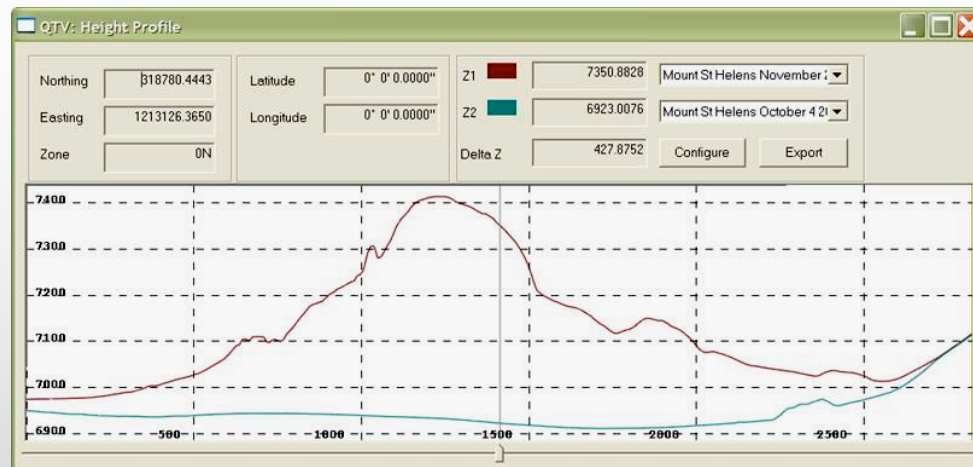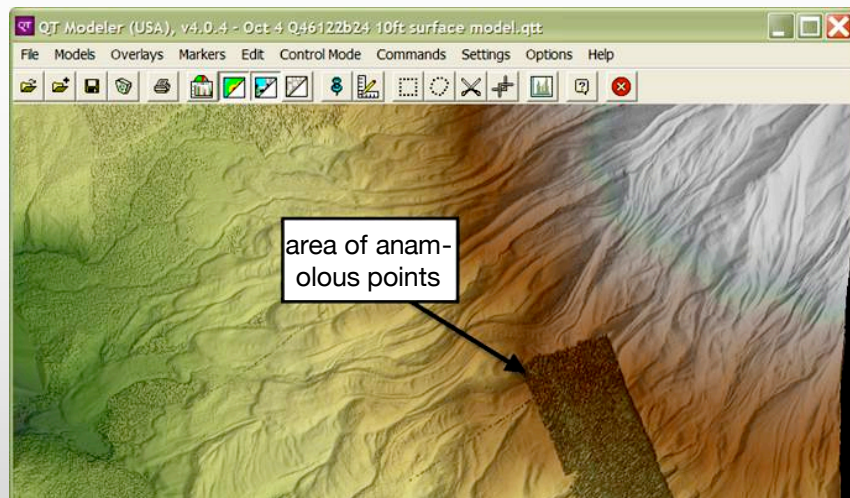Figure 5: Flood Simulation - Result of flood simulation at two different flood stages.

Figure 6: Change detection map quickly highlights changes to terrain.

Applied Imagery's QT Modeler

area of anam-olous points

Profile change
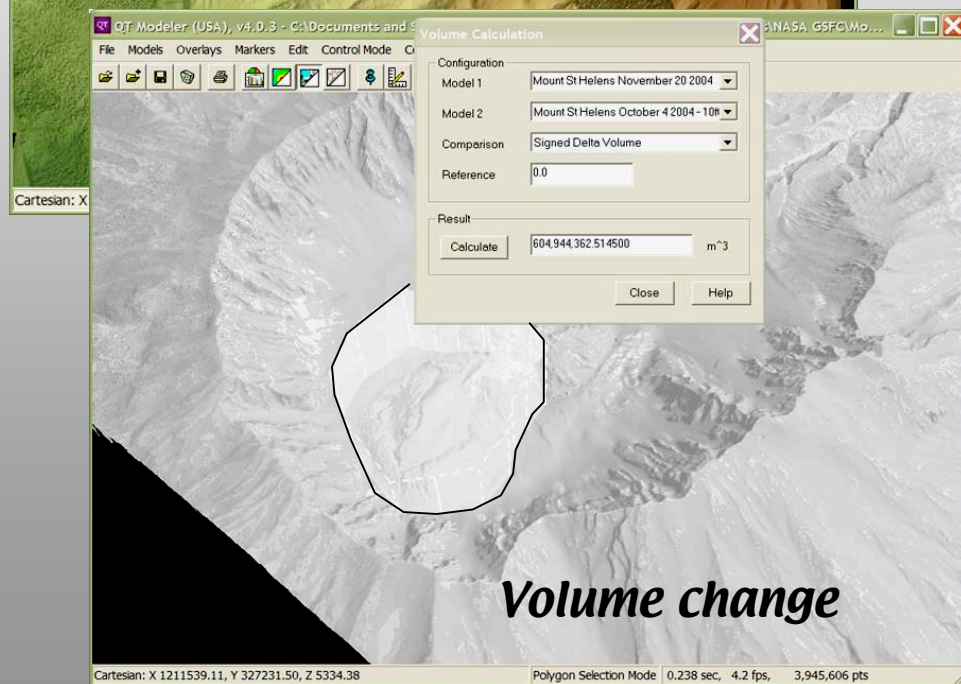
Volume change
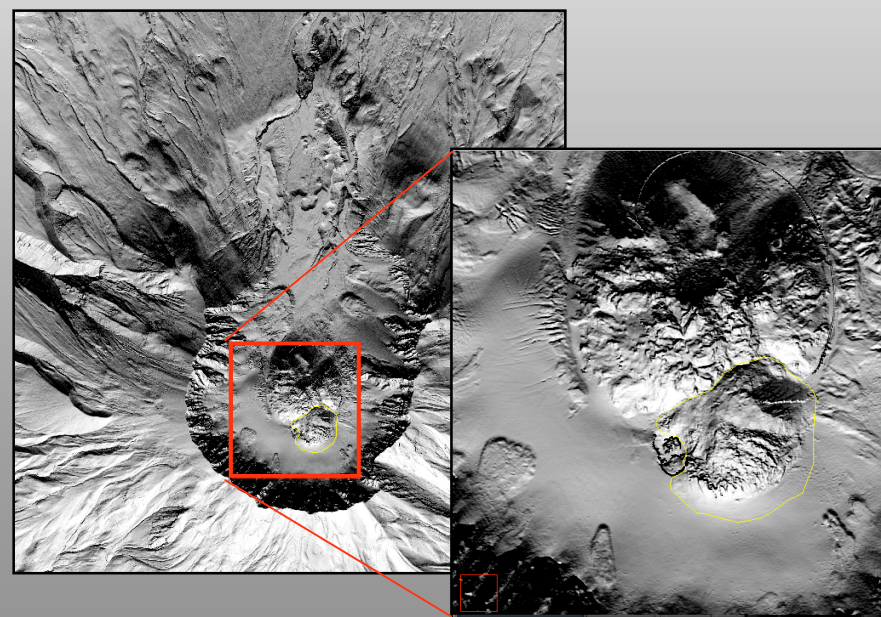
Applied Imagery's QT Reader

DESCRIPTION:

- Subset of QT Modeler funtions

- Tool for visualizing large, complex 3-D models

- Load surface models up to 200 million points

- Load point clouds up to 100 million points

- View model statistics, save views, and play movies in QMV format

PLATFORM: Windows 2000/XP

SYSTEM REQUIRMENTS:
    An 850-MHz Pentium III with 384 MB of RAM and a 3-D graphics card that supports OpenGL

PRICE: Free   URL: http://www.appliedimagery.com

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

InnovMetric's PolyWorks

DESCRIPTION:

- Process point cloud data, geared to terrestrial 3-D laser scanners for surveying applications

- Handle data sets that include up to 100 million data points

- Manages point clouds by using user-defined grid cells uniformly distributed along the XY plane

- View data in 3-D; make measurements; analyze points to detect outliers; merge data from different scans; integrate data with floor plans, engineering drawings, survey data, etc.; generate contours, profiles and cross sections; calculate volumes; generate CAD models and exported to MicroStation and AutoCAD

PLATFORM: Windows NT/2000/XP

SYSTEM REQUIRMENTS:
A 2-GHz CPU, 512 MB of RAM, 3 GB of disk space and OpenGL

PRICE: $12,000 to $21,000   URL: http://www.innovmetric.com/Surveying/english/home.html

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

InnovMetric's PolyWorks

① MULTIPLE SCAN ALIGNMENT

- PolyWorks combines point matching and a powerful best-fit alignment method to align scans using the geometrical shape of the scene.
- No field targets are required for the alignment. However, markers can be used in the scene to validate the alignment results.
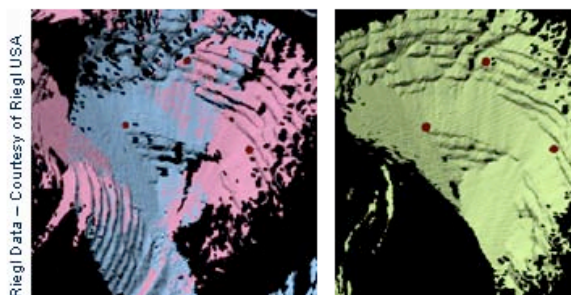
Interactive side-by-side mode for matching points

The field equipment
Optech ILRIS 3D Laser Scanner

② POINT CLOUD GEO-REFERENCING (in real-world coordinates)
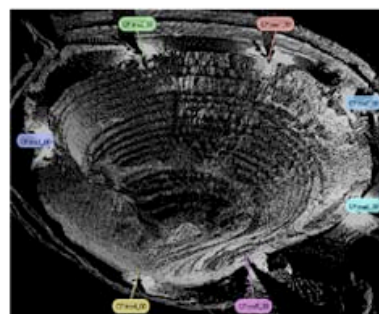
The aligned point cloud is geo-referenced in "local" mine coordinates using a minimum of three known point coordinates
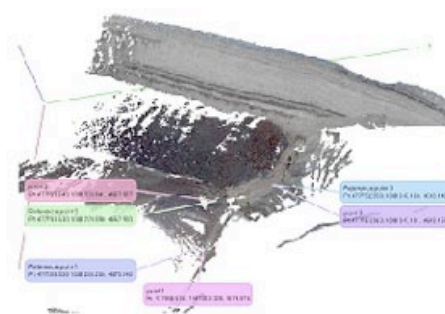
The geo-referencing consists in matching the target points in the scene to their corresponding GPS points

http://www.innovmetric.com/Surveying/english/home.html

InnovMetric's PolyWorks / IMView

DESCRIPTION:

- Software for viewing point cloud data

- Visualize extracted elements in 3-D

- Perform interactive measurements (length, height, angle, radius, volume and cross-section

- Generate reports in Excel, Word and HTML formats

PLATFORM: Windows

SYSTEM REQUIRMENTS: ?

PRICE: Free   URL: http://www.innovmetric.com/Surveying/english/home.html

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

INPHO GmbH's SCOP++

DESCRIPTION:

- Designed for digital terrain modeling with capabilities for interpolating and filtering digital terrain data, and for overlaying raster and vector graphics
- Can import and export digital images, digital terrain models, and vector data
- LIDAR module uses hierarchical filtering techniques that enable processing of large amounts of data for automatic classification of raw point cloud data into terrain and off-terrain
- Analyzer and Visualizer modules provide analysis and perspective viewing functions
- TopDM module geocoded relational database for very large data set managing and archiving

PLATFORM: Windows NT/2000/XP

SYSTEM REQUIRMENTS:
A PC with 64 MB of RAM (256 recommended), 50 MB of disk space, and a 1024 x 768 display

PRICE: Kernel Module: $5,000; TopDM Module: $8,000   URL: http://www.inpho.de/
LIDAR, Analyzer & Visualizer Modules: $4,000 each

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

INPHO GmbH's DTMaster

DESCRIPTION:

- Editing and quality control of digital terrain models (DTMs) and LIDAR data

- Users can check, edit, visualize and classify 3-D point cloud data generated by LIDAR systems or by MATCH-T software

- Tools for visualization, numeric plausibility checking, interactive data editing, 3-D perspective views and measurements, contour generation, and hill-shading

PLATFORM: Windows 2000/XP

SYSTEM REQUIRMENTS:
A high-end PC with one GB of RAM and a high-capacity disk system. Stereo viewing requires a 21" 120-Hz monitor and an OpenGL graphics card that supports quad-buffer stereo.
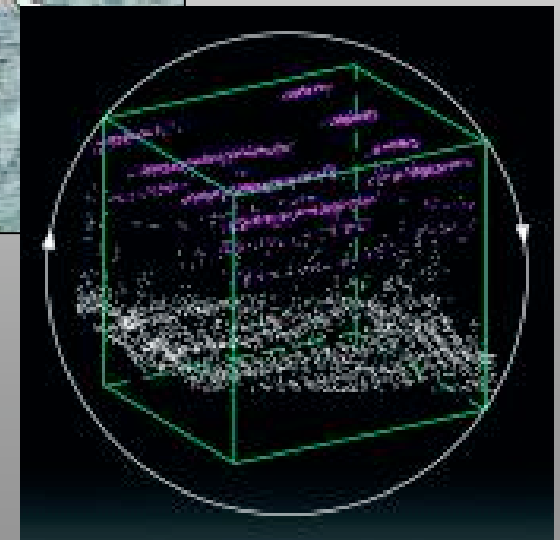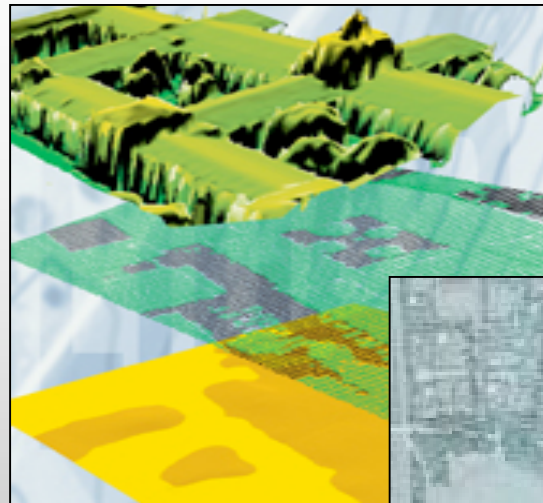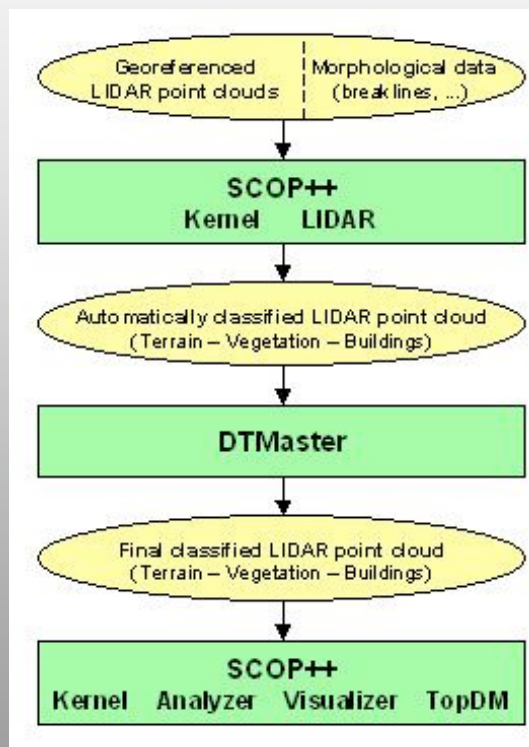
PRICE: $3,500   URL: http://www.inpho.de/

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

INPHO GmbH's SCOP++ and DTMaster

Georeferenced LIDAR point clouds | Morphological data (breaklines, ...)

↓

SCOP++
Kernel   LIDAR

↓

Automatically classified LIDAR point cloud
(Terrain – Vegetation – Buildings)

↓

DTMaster

↓

Final classified LIDAR point cloud
(Terrain – Vegetation – Buildings)

↓

SCOP++
Kernel   Analyzer   Visualizer   TopDM

http://www.inpho.de/

Interactive Visualization Systems (IVS) Fledermaus

DESCRIPTION:

- Intuitive interface for exploring very large, multiple data sets simultaneously in a 3D scene

- Analyze data sets with profiles, histograms, contours, and surface differences

- Import gridded data, imagery, points, lines, solid models, and seismic data

- Selection tools for point query, interactive data editing and coloring, cross-section delineation

- Generate a digital terrain map from ungridded data and display with realistic shading

- Visualization displayed with 3D stereo graphics hardware (e.g., for GeoWalls)

- Edit and analyze bathymetric lidar waveform data (Professional version only)

- No tools explicitly for LiDAR point cloud attribute display or analysis

PLATFORM: Windows 98/NT/2000/XP platforms, Linux, SGI, Sun, and Mac OS

SYSTEM REQUIRMENTS:
 3-D OpenGL graphics card, 256 MB of RAM, a 600-MHz CPU, 1024 x 768 display

PRICE: Standard: $10,000; Professional: $18,500   URL: http://www.ivs3d.com/
        (significant academic discounts available)

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November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

Interactive Visualization Systems (IVS) Fledermaus

http://www.ivs3d.com/
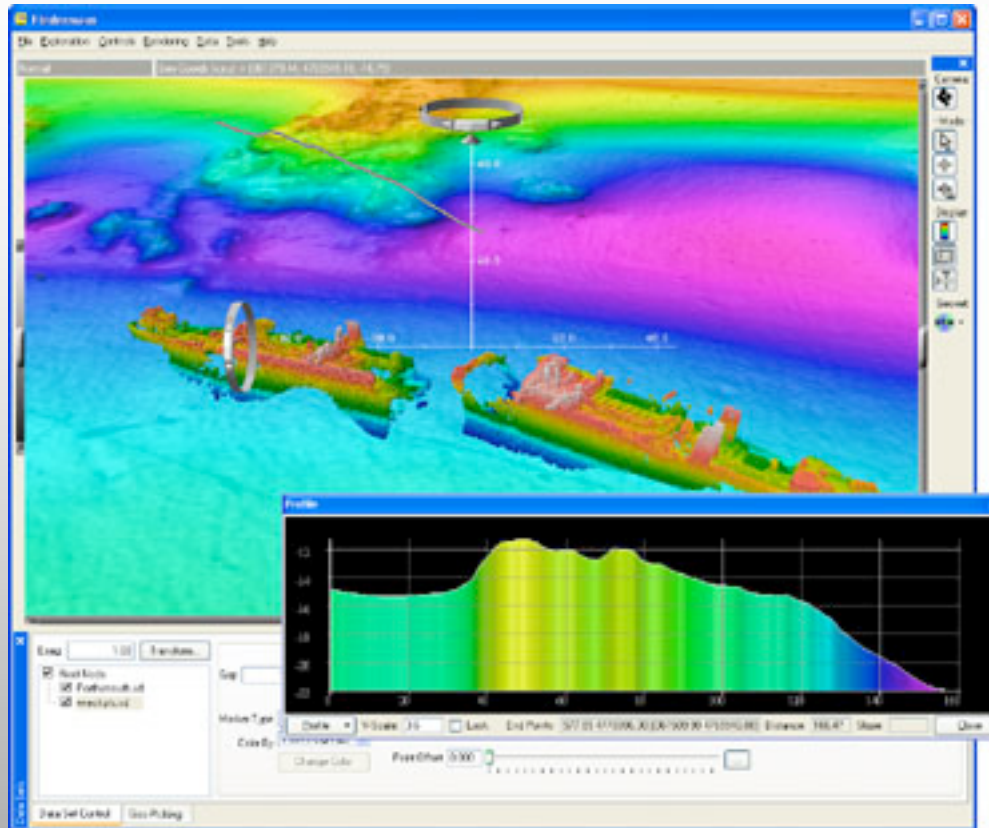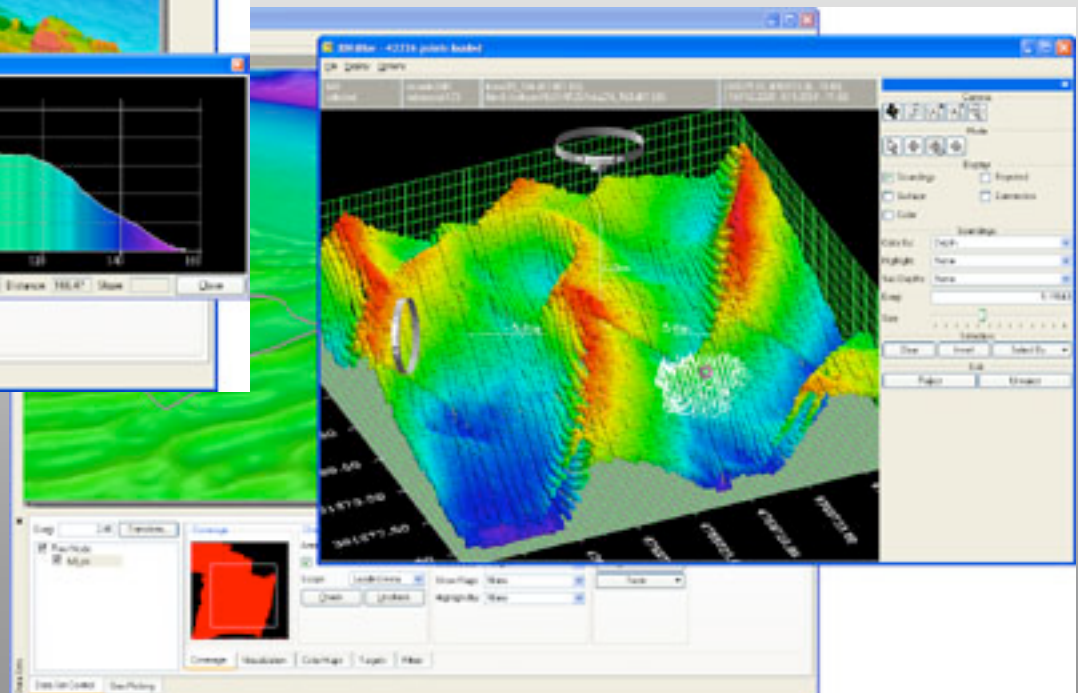
Interactive Visualization Systems (IVS) iView3D

DESCRIPTION:

- Stand alone application that is freely available

- Provides basic 3D interactive exploration and geo-coordinate display for any data set or scene prepared with Fledermaus

- Available as an ActiveX component that can be integrated with many different types of ActiveX containers, such as Microsoft Internet Explorer and Microsoft PowerPoint, and can also be embedded in the development of a software application

PLATFORM: Windows 98/NT/2000/XP platforms, Linux, SGI, Sun, and Mac OS

SYSTEM REQUIRMENTS: ActiveX component is Windows only

PRICE: free   URL: http://www.ivs3d.com/products/iview3d/

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

Pointools View

DESCRIPTION:

- Primarily for viewing point cloud data including from terrestrial scanners and, for LIDAR data, from LAS and TerraScan BIN files

- Can handle hundreds of millions of points

- View 3-D models along with point clouds, make measurements (including point-to-point), and maneuver through data

- Point cloud data can be clipped to a user-defined box.

- Import 3-D models from 3D Studio (3DS), Lightwave (LWO) and Wavefront (OBJ)

PLATFORM: Windows 98/NT/2000/XP platforms, Linux, SGI, Sun, and Mac OS

SYSTEM REQUIRMENTS:
A 500-MHz Pentium III or better, 512 MB of RAM, a 64-MB video card and 20 MB of hard disk

PRICE: $500   URL: http://www.pointools.com/index.php

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

Pointools View

http://www.pointools.com/index.php
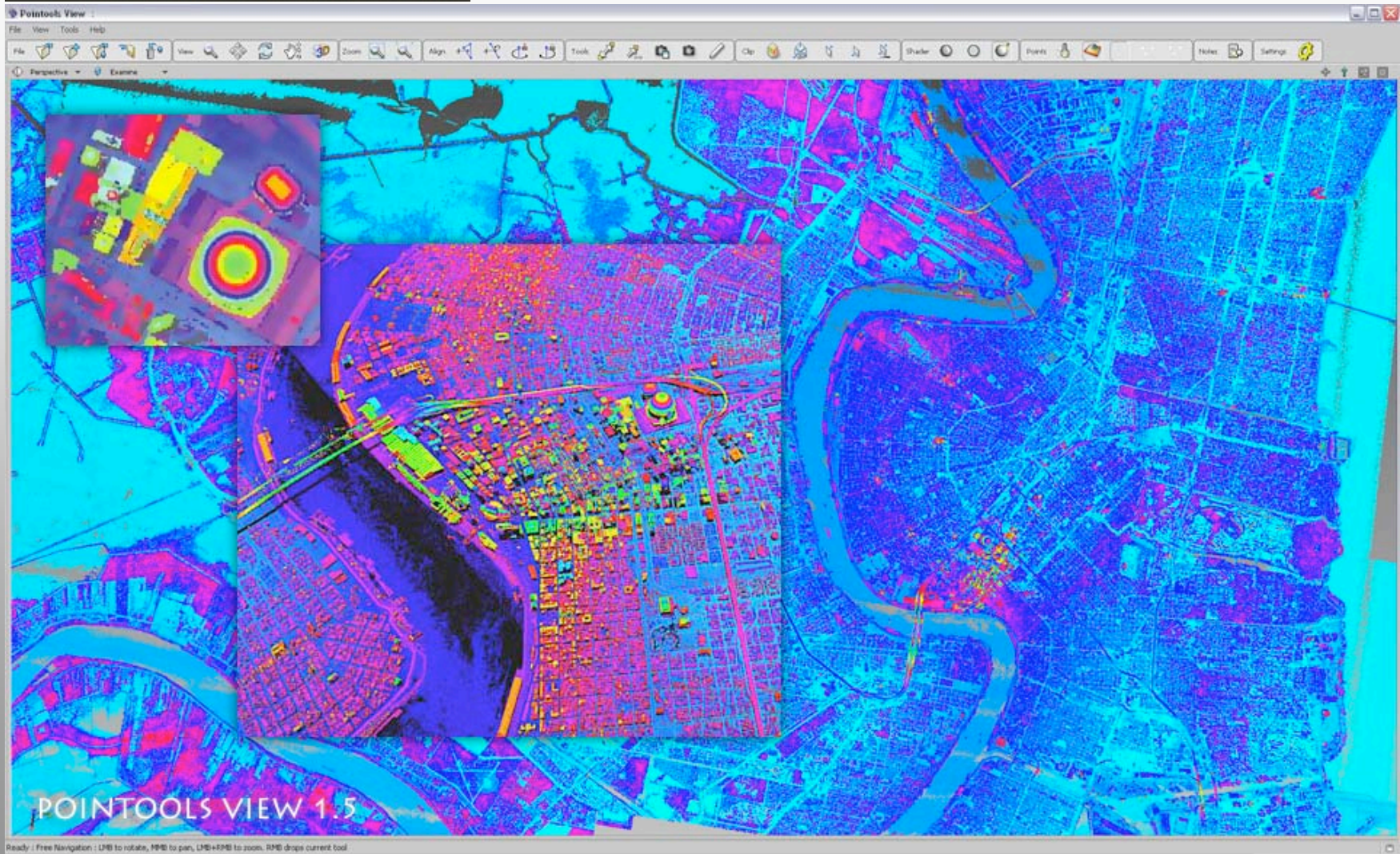
ProLogic's LIDAR Explorer

DESCRIPTION:

- ArcGIS Extension for integration of LAS-formatted point data in ArcMap and ArcScene

- Import tool converts ASCII or binary point data to LAS and creates a separate spatial indexing file specific to LAS data to improve speed of spatial operations

- 2-D and 3-D tools for viewing, profiling and selection with point symbology for elevation, classification, intensity, return number, extracted image color, or user defined parameter

- LIDAR Toolkit with built-in classification, gridding and analysis functions, user implementation of custom algorithms, and results stored in user-defined ArcGIS database linked to LAS file

PLATFORM: Windows

SYSTEM REQUIRMENTS:
High-end PC with ESRI's ArcGIS 9.0 or later, .NET support installed and 3D Analyst

PRICE: NASA GSFC SBIR Phase II Beta Release   URL: http://www.prologic-inc.com
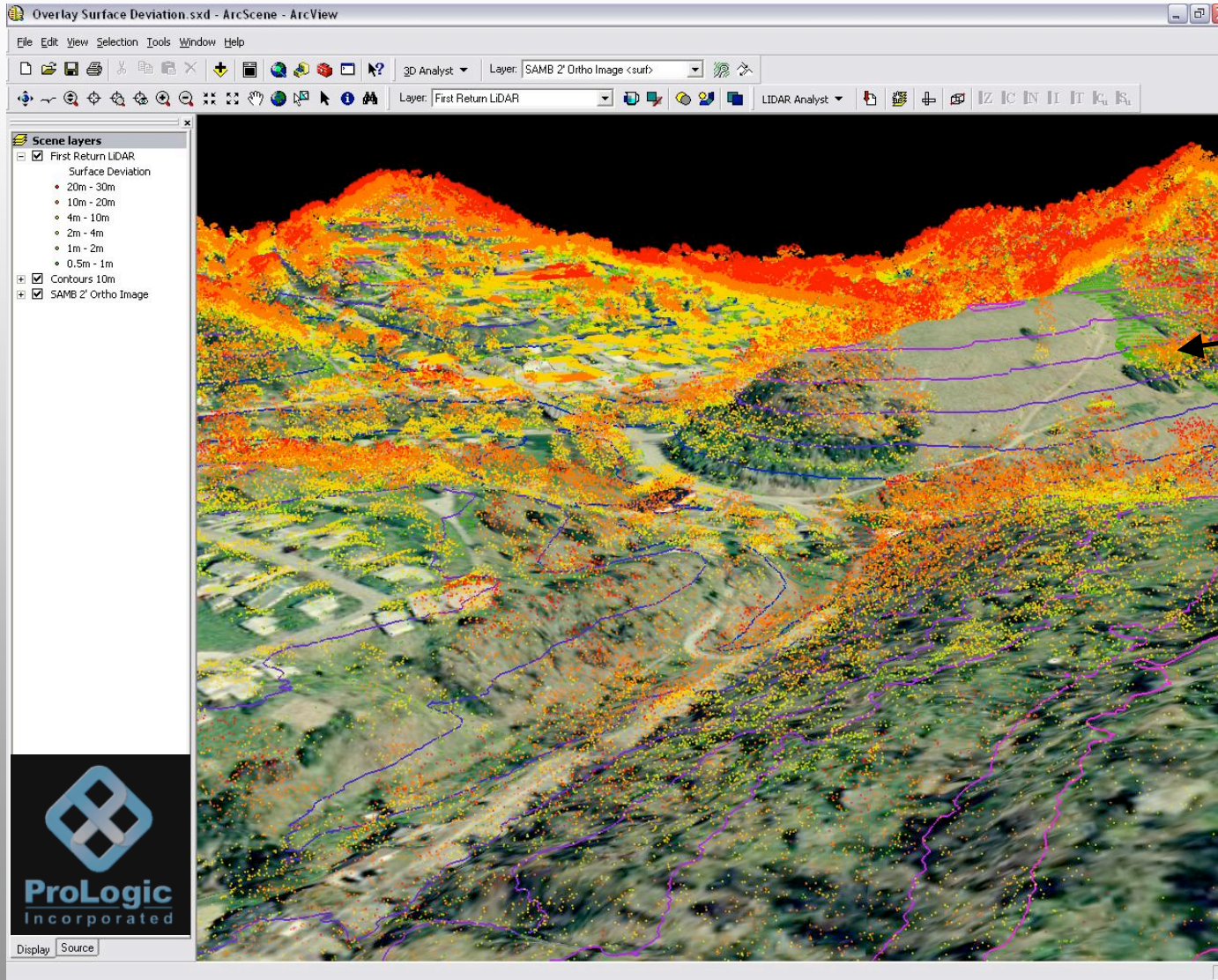(commercial price is TBD)

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/
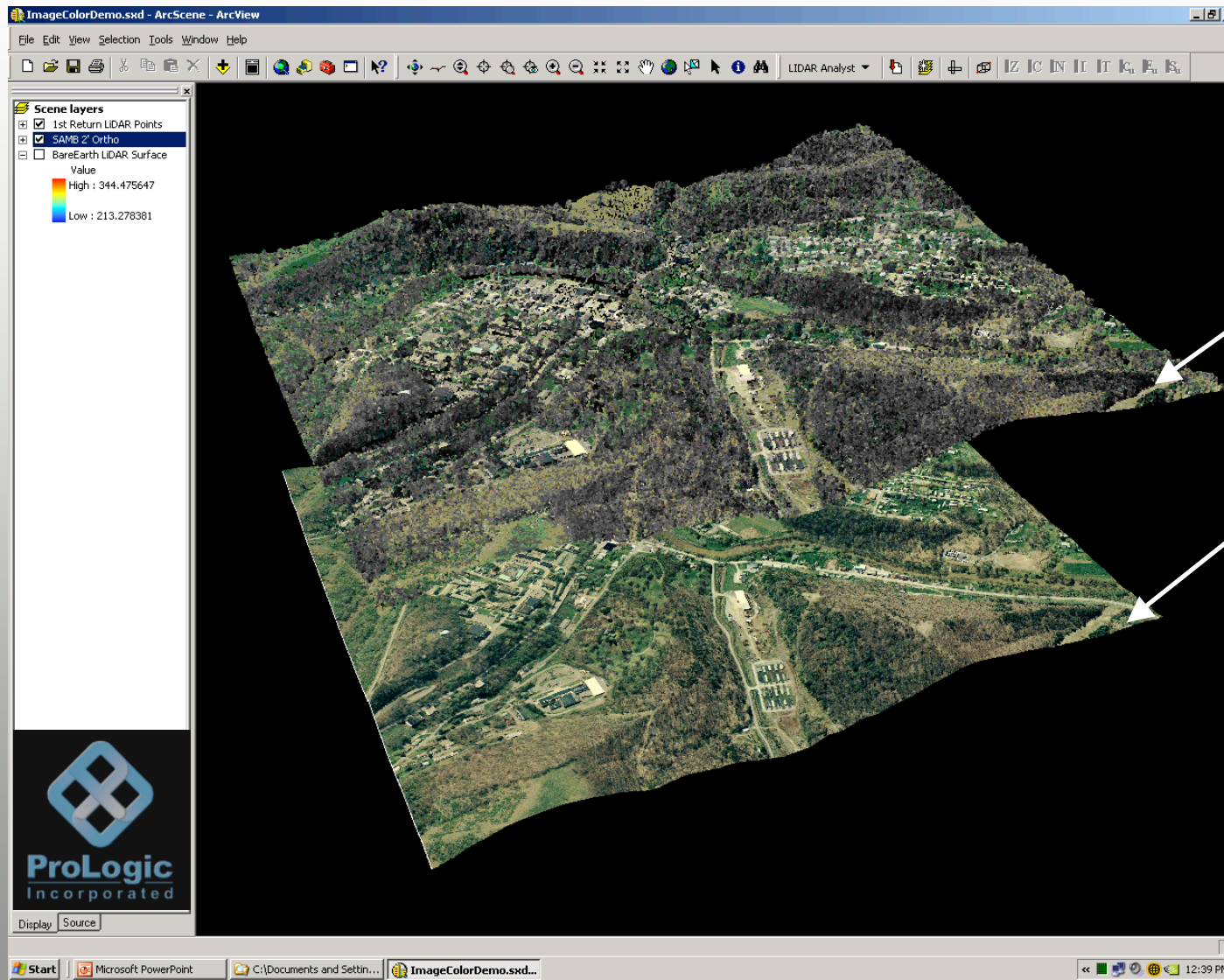
ProLogic's LIDAR Explorer

LIDAR point cloud colored by height above ground overlayed on orthophoto with elevation contours
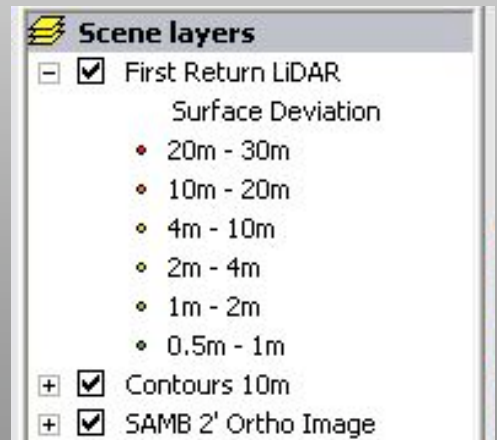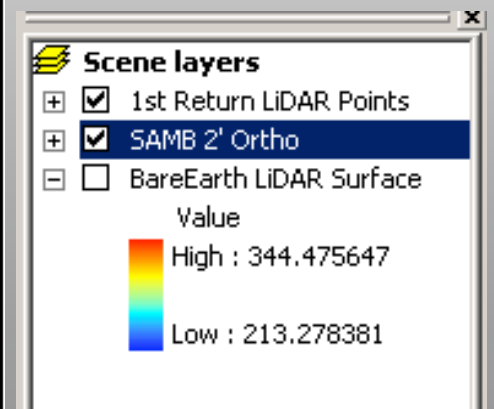
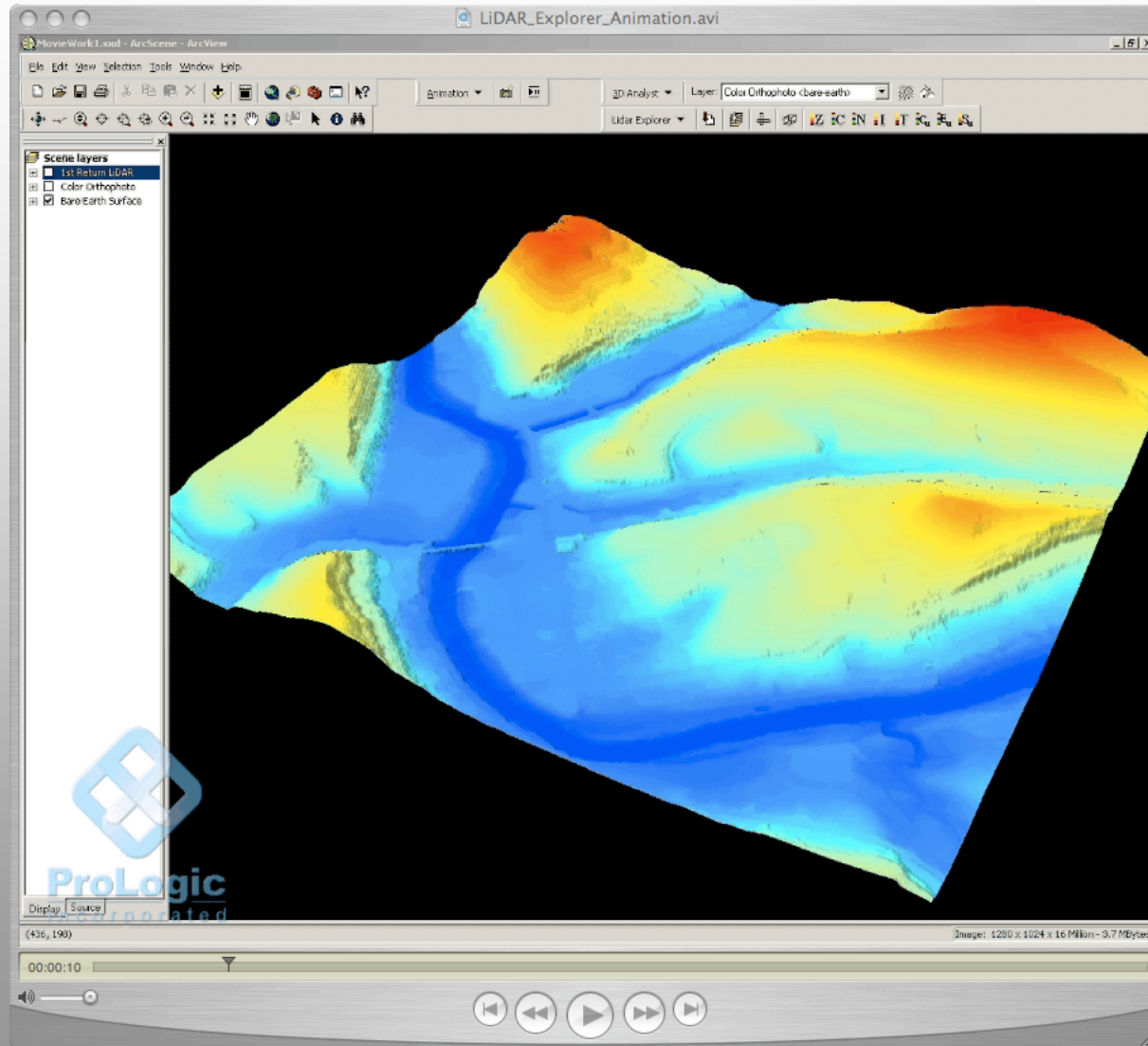# ProLogic's LIDAR Explorer

LIDAR point cloud with point color extracted from orthophoto

Orthophoto

ProLogic's LIDAR Explorer

Export animations to avi movies

Terrasolid's TerraScan

DESCRIPTION:

- A specialized, production-oriented application designed for classifying and processing large point cloud data sets suitable for both terrestrial and airborne survey applications

- Integrated with Bentley MicroStation, which provides tools and capabilities for view manipulation, visualization, vector placement, labeling and plotting

- View point clouds in 3-D, define point classes (e.g., ground, vegetation, buildings), remove erroneous points, thin and smooth data, digitize by snapping to points, project points into profiles, export elevation-colored and intensity-colored raster images, create fly-throughs

PLATFORM: Windows 95/98/NT/2000

SYSTEM REQUIRMENTS:
PC with 500 MB of RAM per 20 million points, and Bentley MicroStation CAD software (next release will not require use of MicroStation)

PRICE: $5,700, not including MicroStation   URL: http://www.terrasolid.fi/

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

Terrasolid's TerraModeler

DESCRIPTION:

- Terrain modeling application can create triangulated irregular network (TIN) surface models of the ground or design surfaces using survey data, graphical elements or ASCII XYZ text files
- Integrated with Bentley MicroStation, which provides tools and capabilities for view manipulation, visualization, vector placement, labeling and plotting
- Users can edit TINs on a point-by-point basis, divide different types of surface regions into separate domains, calculate volumes between two surfaces, and generates contour maps automatically

PLATFORM: Windows 95/98/NT/2000

SYSTEM REQUIRMENTS:
PC with 500 MB of RAM per 20 million points, and Bentley MicroStation CAD software (next release will not require use of MicroStation)

PRICE: $3,400, not including MicroStation   URL: http://www.terrasolid.fi/

SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

Terrasolid's TerraScan and TerraModeler

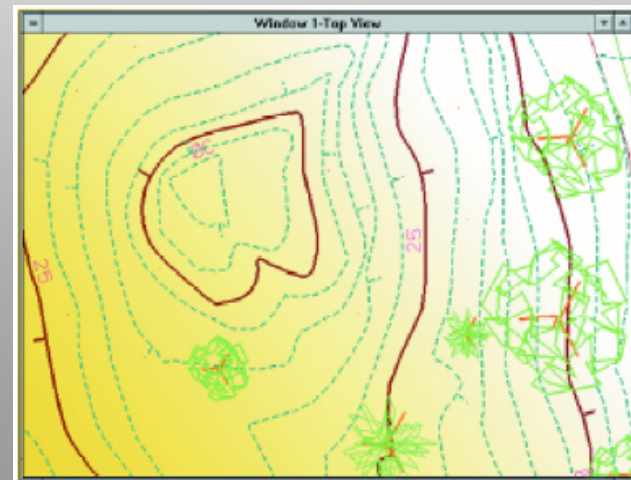**Terrasolid**
http://www.terrasolid.fi/

Point cloud classification
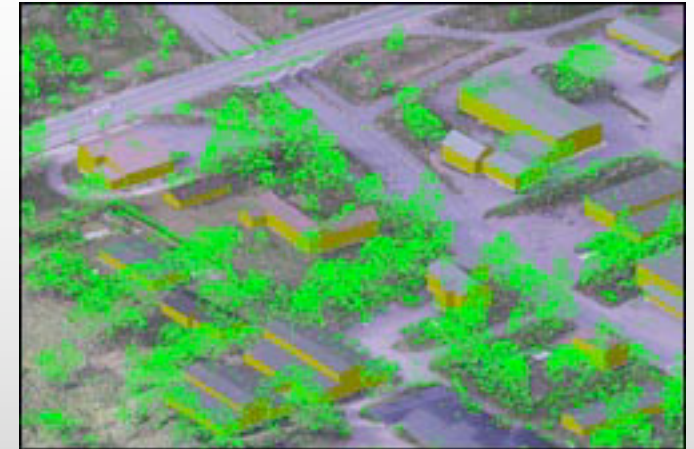
Automated building detection
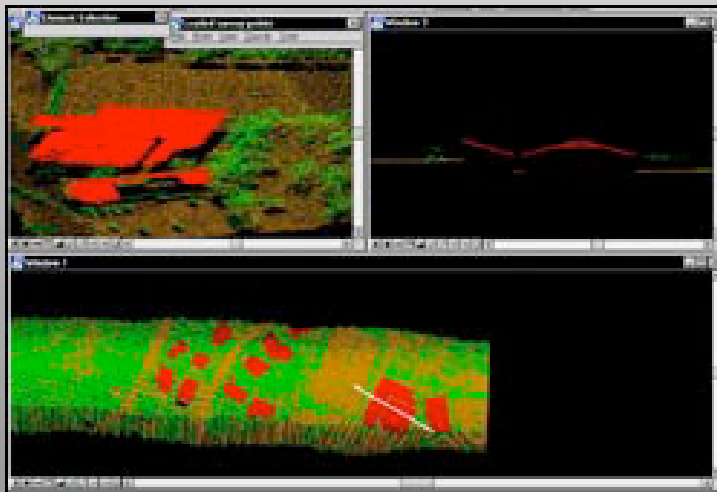
Multiple data views

Terrain model creation

Visual Learning System's LIDAR Analyst

DESCRIPTION:

- Extension plug-in for ESRI's ArcGIS or ERDAS Imagine

- Designed to automate the collection of 3-D features from LIDAR data

- Includes tools for editing points and DEMs, modifying bare-earth surfaces, extracting bare-earth surfaces, buildings, and trees, and editing complex polygons

- Extracts feature attributes (e.g., building height and roof type, tree height and crown width)

- Compliments VLS's Feature Analyst extension for high-resolution image analysis

PLATFORM: Windows 95/98/ME/2000/NT/XP

SYSTEM REQUIRMENTS:
   PC running ArcGIS with Spatial Analyst, or ERDAS Imagine

PRICE: $13,000, not including ArcGIS or Imagine   URL: http://www.vls-inc.com/
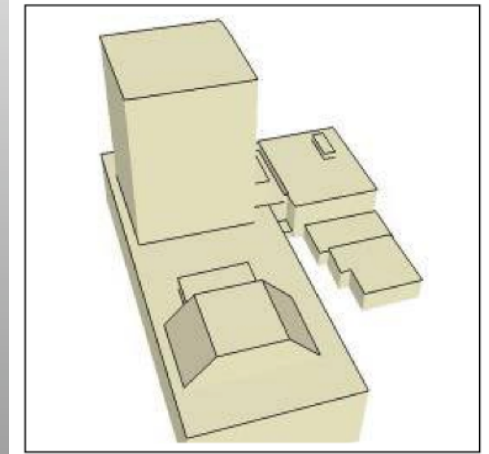
SURVEY OF TERRAIN VISUALIZATION SOFTWARE
November 2005, U.S. Army Topographic Engineering Center, http://www.tec.army.mil/TD/tvd/survey/

Visual Learning System's LIDAR Analyst

http://www.featureanalyst.com/
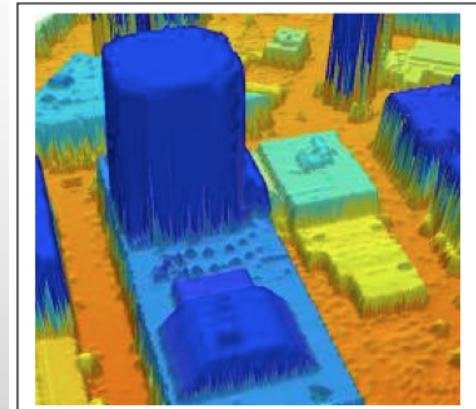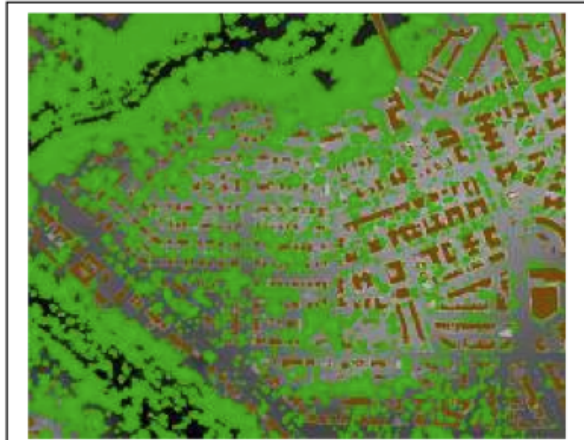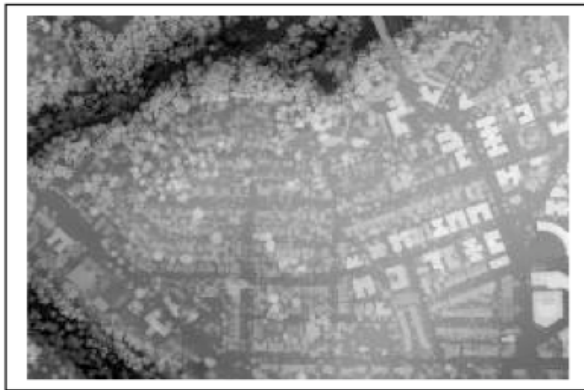
LIDAR data (top) and extracted features (bottom).
Forest and buildings (left), buildings and bald Earth (center), complex building (right).

Commercial Software not Explicitly for LiDAR Data

Many software packages, not explicitly for LiDAR, have functionaly for gridding XYZ point data. An example:

Waterloo Hydrogeologic's SURFER

- *Interpolation and gridding of XYZ point data to produce contour, wireframe, vector, image, and shaded relief maps*

- *Visualization of 3-D perspective views of the gridded products*

- *Does not retain LIDAR attributes of the points (return number, acquistion time, etc.)*

- *Not for interactive viewing, editing, or analysis of the point cloud data itself*

- *Windows platforms; $575*

- *http://westbay.com/software/surfer/surfer_ov.htm*

Commercial LiDAR Software Summary

Waveform Data: *IVS Fledermaus Professional for baythmetric LiDAR*

Point Cloud Data:

Company	Product	Attributes
Applied Imagery	QT Modeler, Reader	Stand-alone viewing, analysis, gridding
InnovMetric	PolyWorks, IMView	Ground-based LIDAR surveying
Inpho GmbH	SCOP++, DTMaster	Stand-alone classification, editing, gridding
IVS	Fledermaus, iView3D	OS-independent viewing, gridding
Pointools	Pointools View	Stand-alone viewing
ProLogic	LIDAR Explorer	Classify, view, analyse, grid in ArcGIS
Terrasolid	TerraScan & Modeler	Production-oriented processing
Visual Learning	LIDAR Analyst	Feature extraction in ArcGIS or ERDAS

No endorsement is implied or granted