LIDAR IMAGERY

From Simple Snapshots to Mobile 3D Panoramas

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Chairman, Optech Incorporated

Lidar systems now provide unique 3D imaging capabilities for:

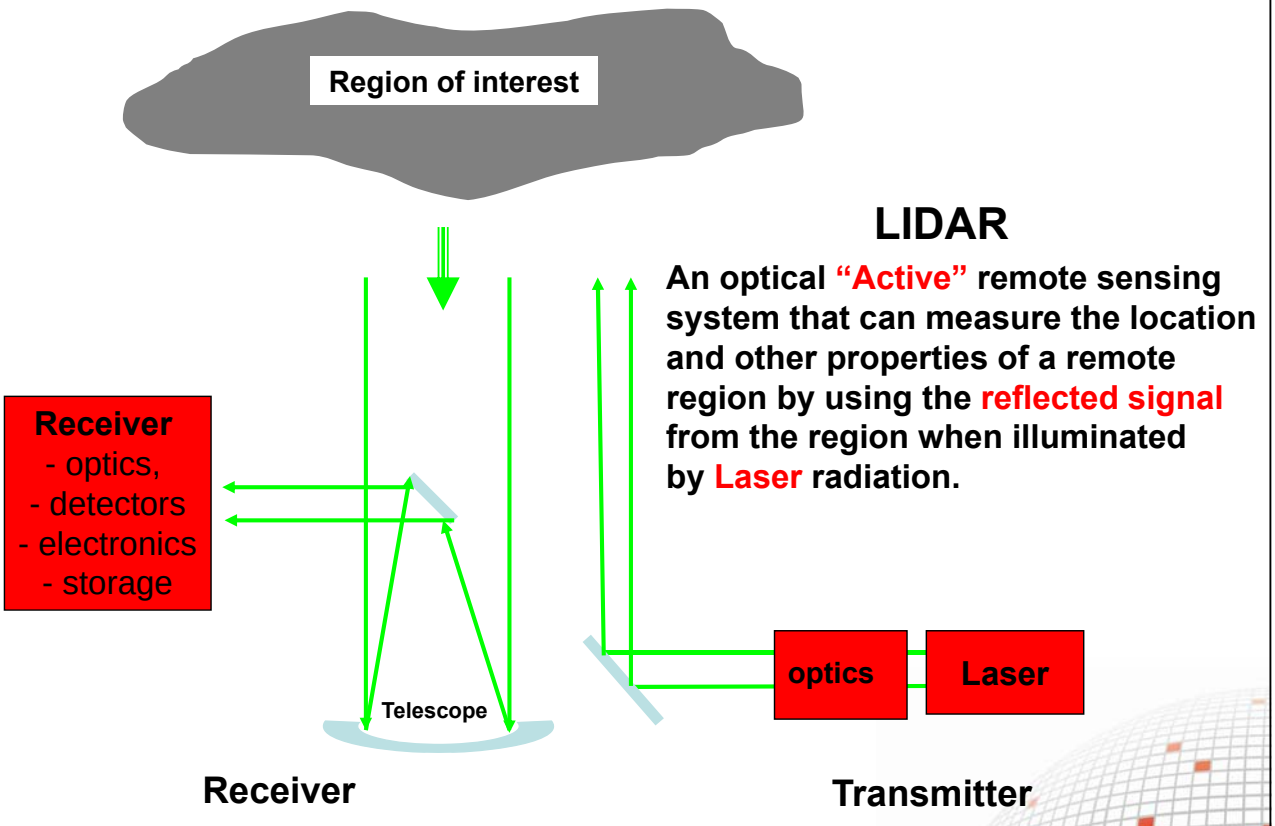
- **Solid object location, shape and structure (surveying, mapping, positioning, vehicle guidance)**

- **Marine and hydrographic measurements (bathymetry, water conditions, sub-surface resources)**

- **Atmospheric monitoring (meteorology, air quality)**

- **Space systems (landing, docking, rendezvous, planetary exploration)**

Schematic Lidar Configuration



LIDAR

An optical "Active" remote sensing system that can measure the location and other properties of a remote region by using the reflected signal from the region when illuminated by Laser radiation.

LASERS

Lasers are unique light sources.
They provide the ability to generate highly controlled optical radiation in a variety of pulsed or modulated continuous wave modes.

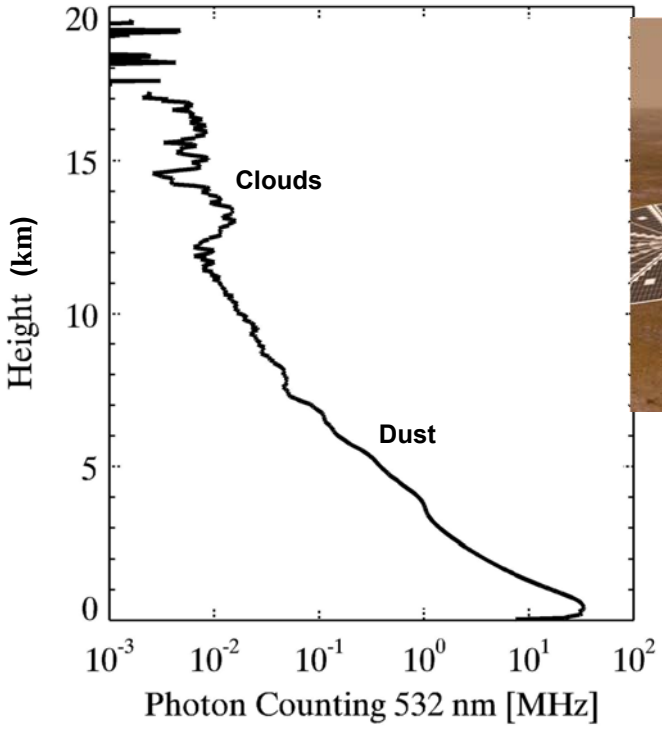
With lasers it is possible to specify and control:

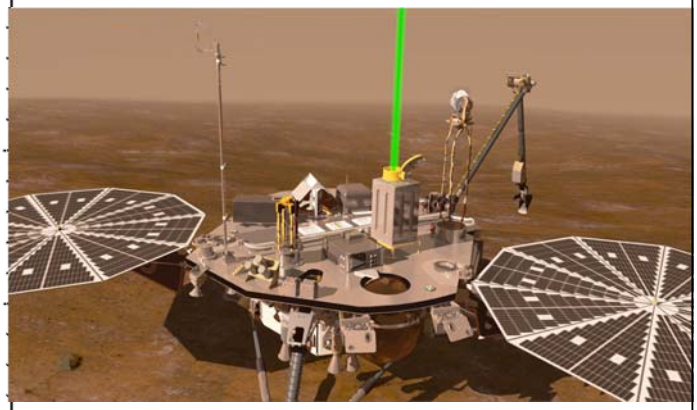
- **Wavelength and wavelength spread, [λ and $\Delta\lambda$]**
- **Wavelength tunability [$\lambda(t)$]**
- **Pulse width and repetition frequency ($\Delta\tau$ and prf)**
- **Output beam direction and beam spread, $\Delta\theta$ and $\theta(t)$**
- **Coherence level**
- **Degree of polarization**
- **Output intensity**
- **Irradiance (power per unit area) on a remote region**

Lidar systems can make use of all of these capabilities To provide unique illumination signatures

BASIC LIDAR RETURN SIGNATURE

First lidar return from the atmosphere of Mars March 2008

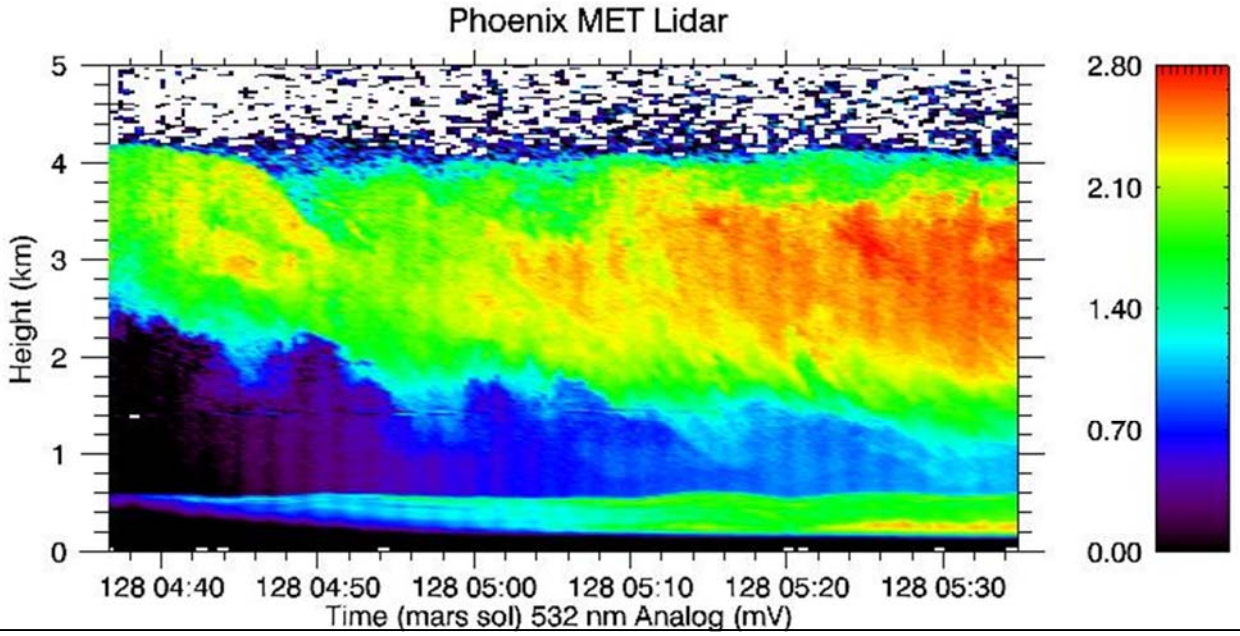




Optech lidar on the NASA 2007 Mars Mission "PHOENIX"

Simple Image from Superposition of Lidar Returns

PHOENIX LIDAR
Discovers
"SNOWFALL"
on Mars
Sol 128 (October 2, 2008)



Active Imaging vs. Passive Imaging

Passive

- Uses reflection of ambient light or thermal emission
- Illumination is generally multi-wavelength
- Reflections are multi-angle
- Limited control over illumination conditions
- Direct X,Y information
- Day/night limitations
- Sun angle and shadow considerations
- Atmospheric limitations (haze, clouds etc.)
- Image Z information requires multi-measurements

Active

- Supplies its own illumination
- Selective control of illumination
  (location, spot size, wavelength, intensity)
- Backscattering dominates
  (*No shadows in basic image)*
- Direct Z information
- Day & night operation
- Reduced atmospheric limitations (Gated imaging)
- Image X,Y information requires multi-measurements

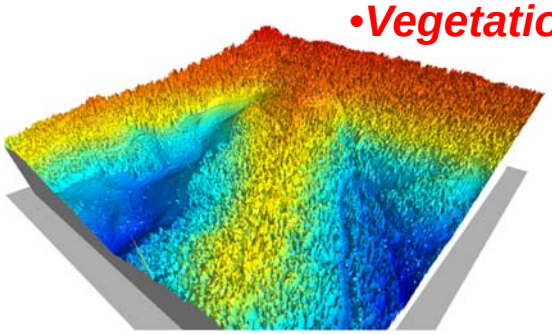
Unique capabilities of Lidar Imagery

- ***Topography of featureless terrain, sand, snow***
- ***Sunlight suppression***

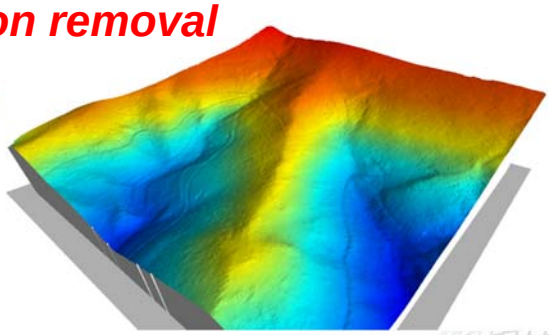
Photograph looking into the sun

LIDAR Image (Sun at +)

- ***Vegetation removal***



DEM before vegetation removal



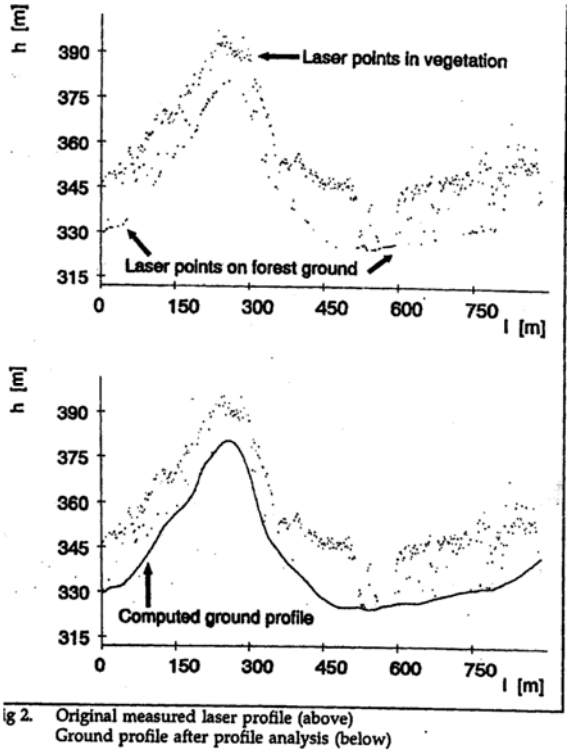
DEM after vegetation removal

Vegetation removal, 1989 data

Figure 2. from

"Methods and Results of High Precision Airborne Laser Profiling",

J. Lindenberger, Photogrammetrische Woche 1991



ig 2. Original measured laser profile (above)
Ground profile after profile analysis (below)

Penetration Rate

Coniferous;	**35.0%**
Deciduous	**24.7%**

Accuracy, 0.15 m

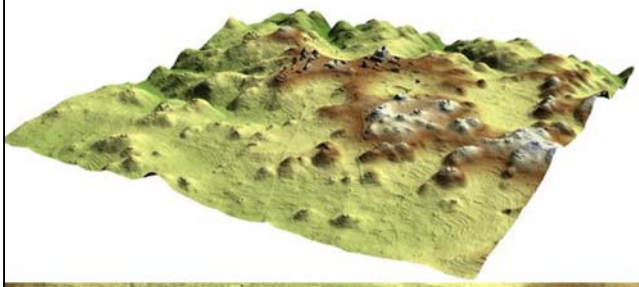
(photogrammetric & terrestrial check)

Recommendation

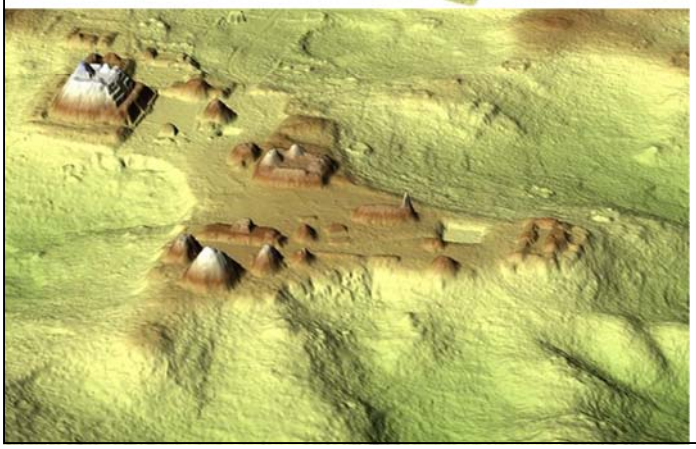
Prf of 33 Hz should be Increased to at least 100 Hz

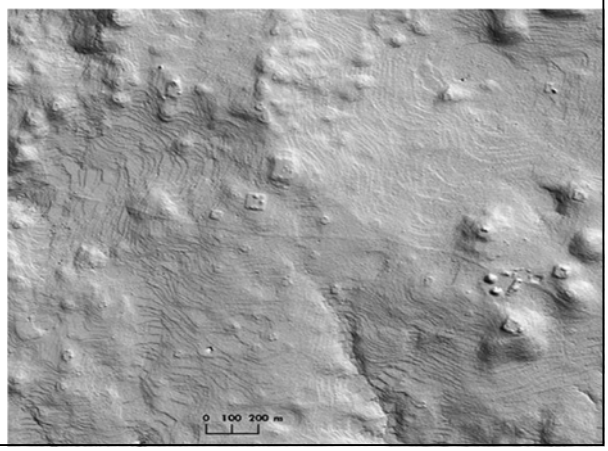
National geographic: “Massive Maya City Revealed by Lasers”

Airborne lasers have "stripped" away thick rain forests to reveal new images of an ancient Maya metropolis that's far bigger than anyone had thought. An April 2009 flyover of the Maya city of Caracol used Light Detection and Ranging (LiDAR) equipment which bounces laser beams off the ground—to help scientists construct a 3-D map of the settlement in western Belize.



The survey revealed previously unknown buildings, roads, and other features in just four days, University of Central Florida anthropologists Arlen and Diane Chase have spent decades hacking through the tangled undergrowth that has engulfed the powerful city—which thrived between A.D. 550 and 900. So far they've uncovered only a tiny fraction of the ruins.
"It's like literally removing all of the plant growth, so that we can see down below," Arlen Chase said.

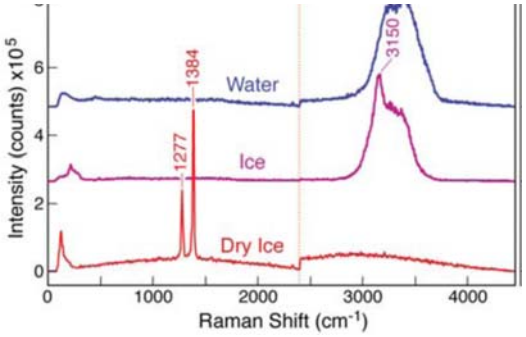


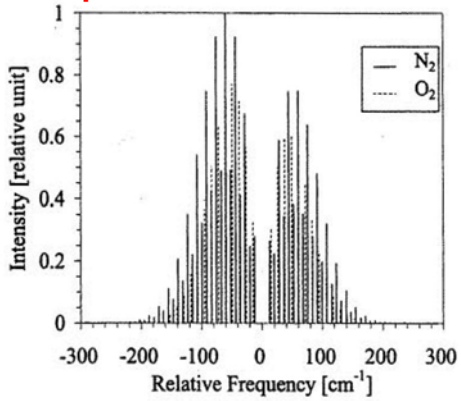


Raman Lidar

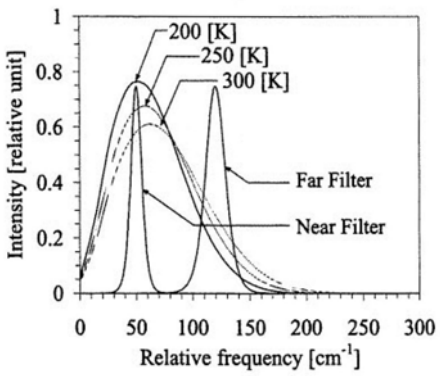
Species identification & temperature

Remote Raman spectra of water, ice and dry ice



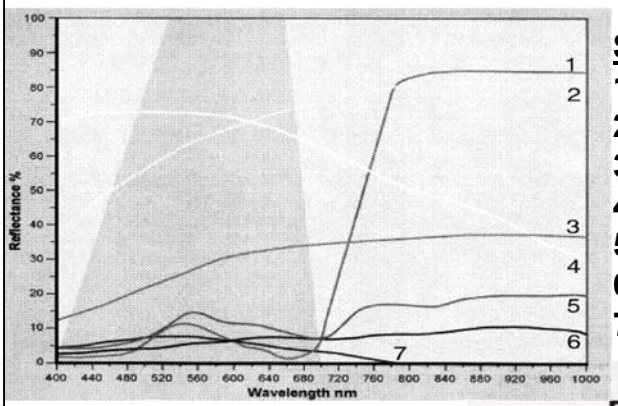


N_2 O_2 Raman Spectra



Rotational Raman Temperature measurement

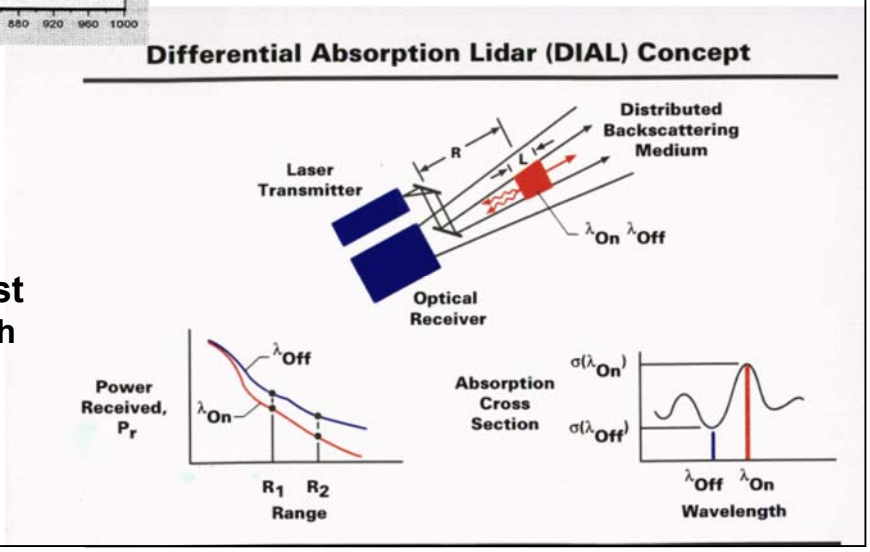
Multi-Wavelength Species Specific Information



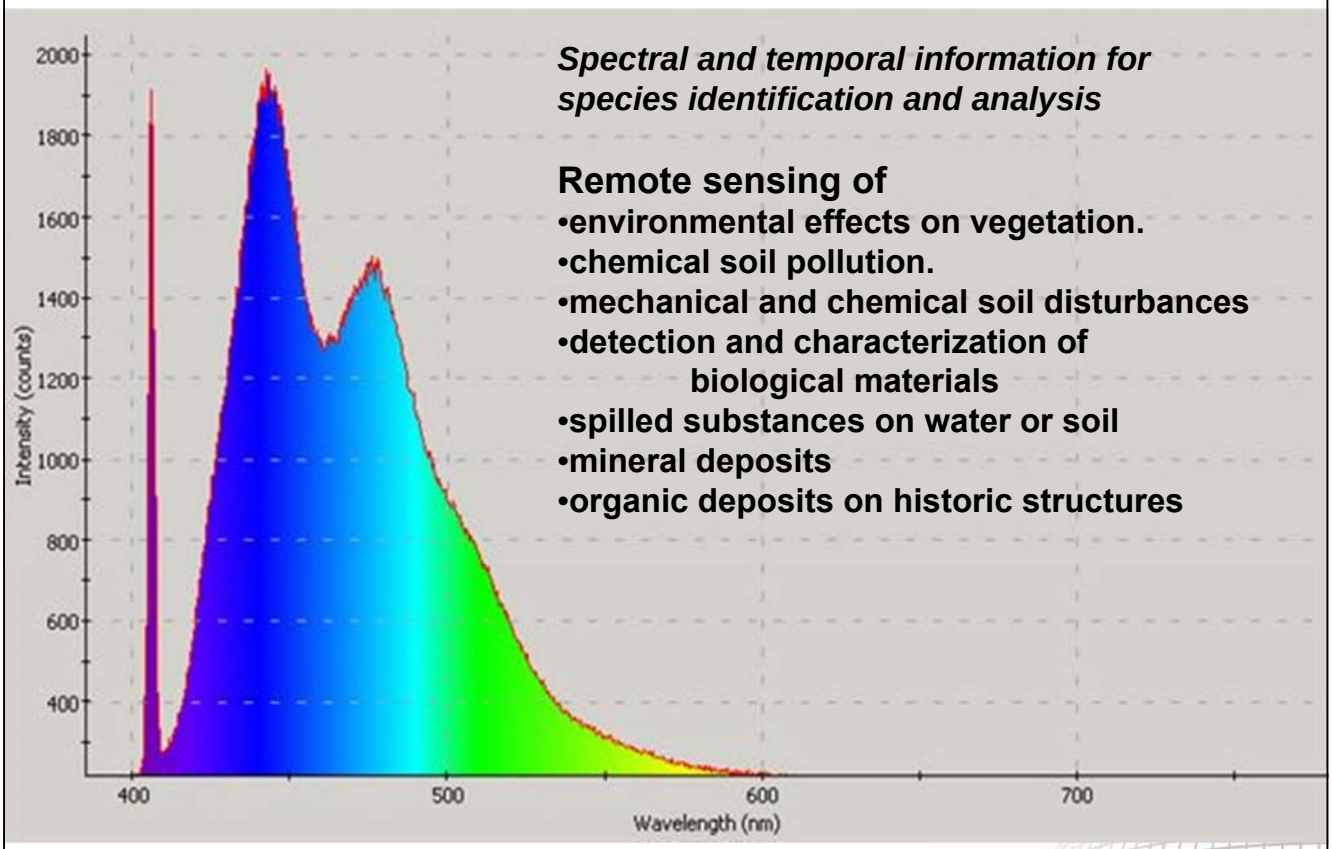
Selective Reflectance

1 Grass
2 Lime Stone
3 Sand, dry
4 Snow, old
5 Fir tree
6 Asphalt, wet
7 Water

DIAL
For species of interest
Use 2 Wavelengths with
(1) Strong absorption
(2) Weak absorption



Fluorescence Lidar



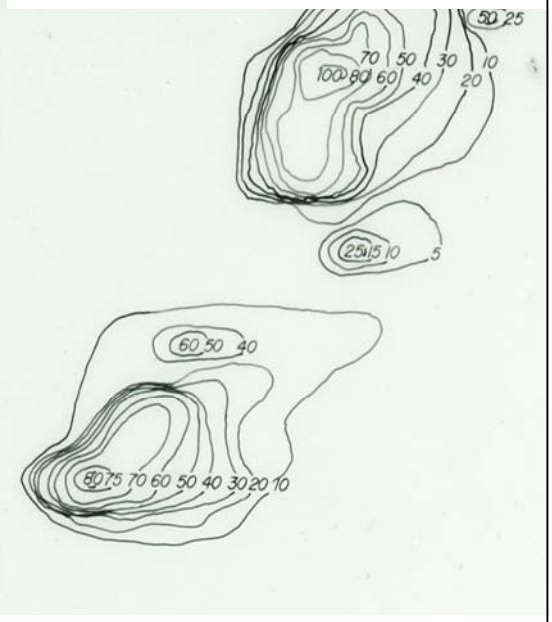
Spectral and temporal information for species identification and analysis

Remote sensing of
- **environmental effects on vegetation.**
- **chemical soil pollution.**
- **mechanical and chemical soil disturbances**
- **detection and characterization of biological materials**
- **spilled substances on water or soil**
- **mineral deposits**
- **organic deposits on historic structures**

1968 My First Lidar

Smoke plume Monitoring

Simple mapping of smoke plume cross-sections



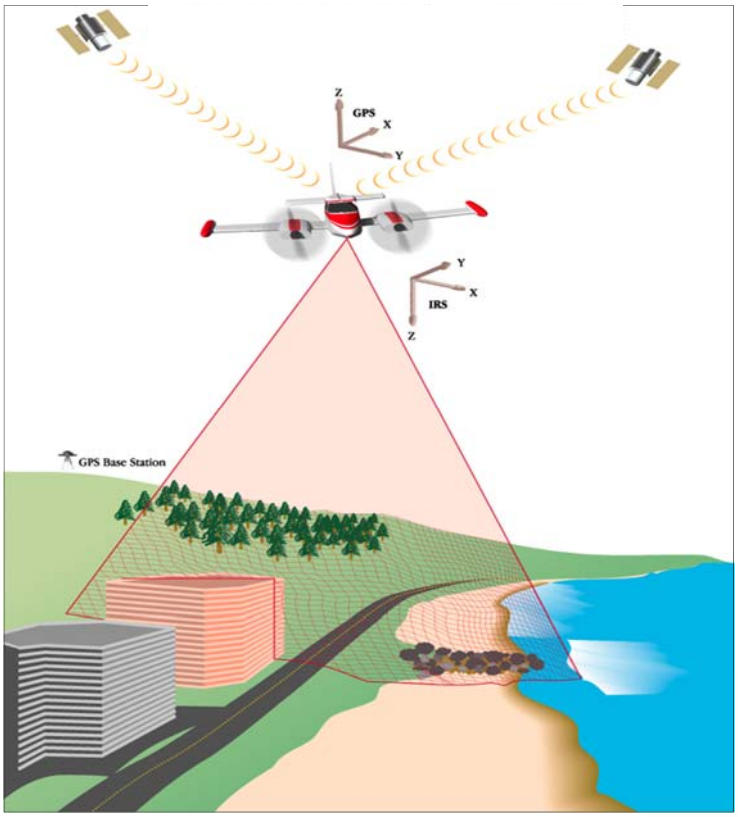
- 100 Megawatt Ruby Lidar
- Prf 0.1 Hz
- Used polarization to identify dust and droplets

"Mobile" Lidar

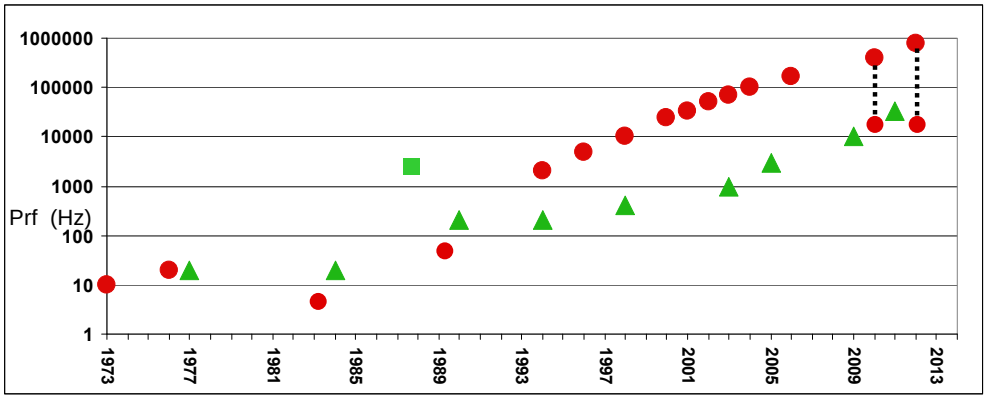
- 5 Ton Truck and
- 10 kilowatt Generator

- Heavy duty mechanical scanning
- Oscilloscope data acquisition

Airborne Laser Terrain Mapping



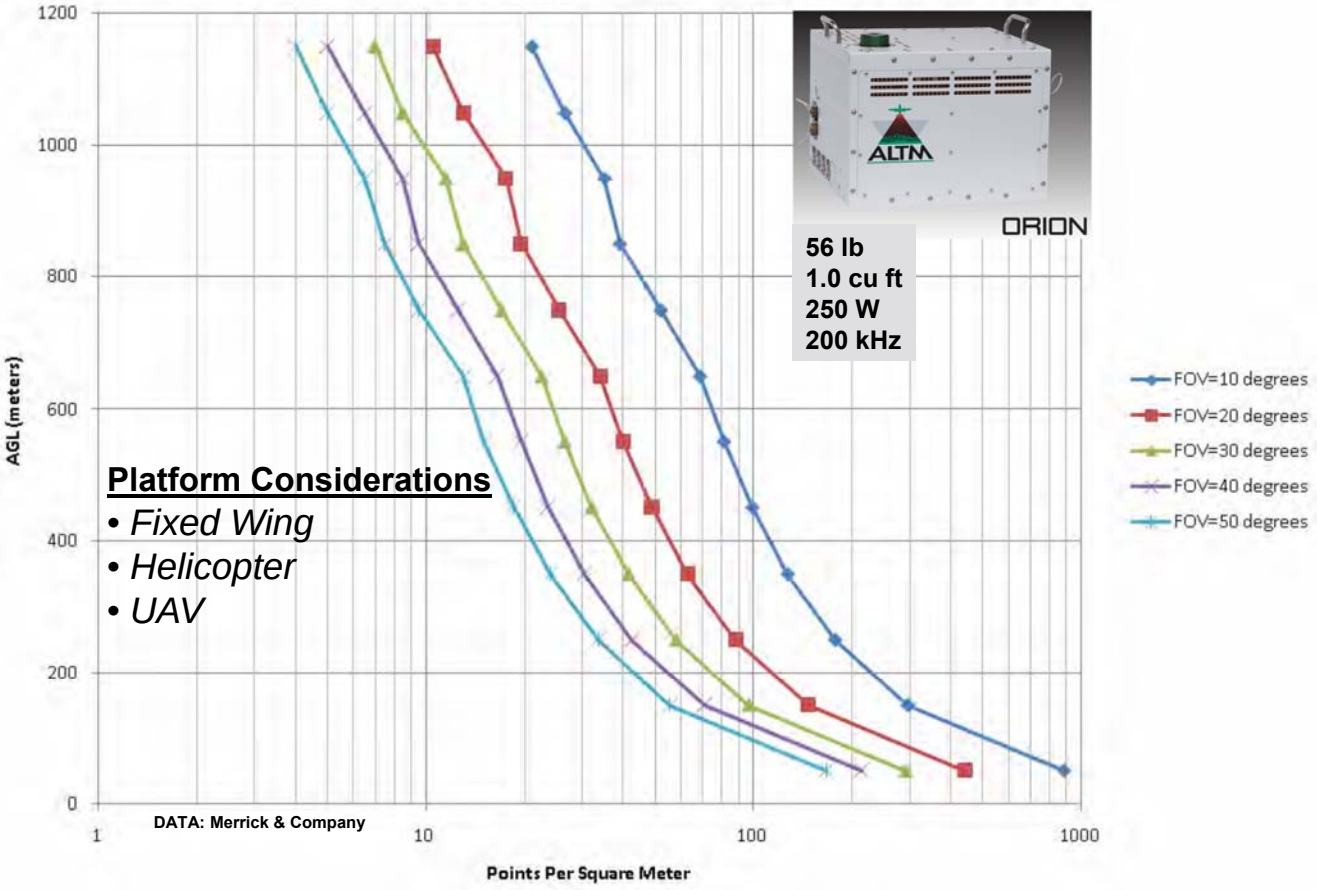
Optech's Lidar prf History



● 1064 nm	Terrestrial
▲ 532 nm	Marine
■ 510 nm	Marine Cu-vapor

LiDAR Densities @ 50 knots for the Optech Orion C200

56 lb
1.0 cu ft
250 W
200 kHz

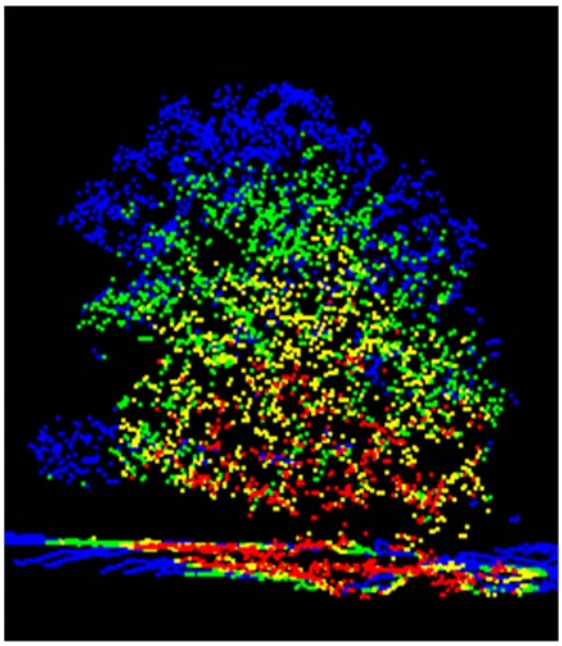


DATA: Merrick & Company

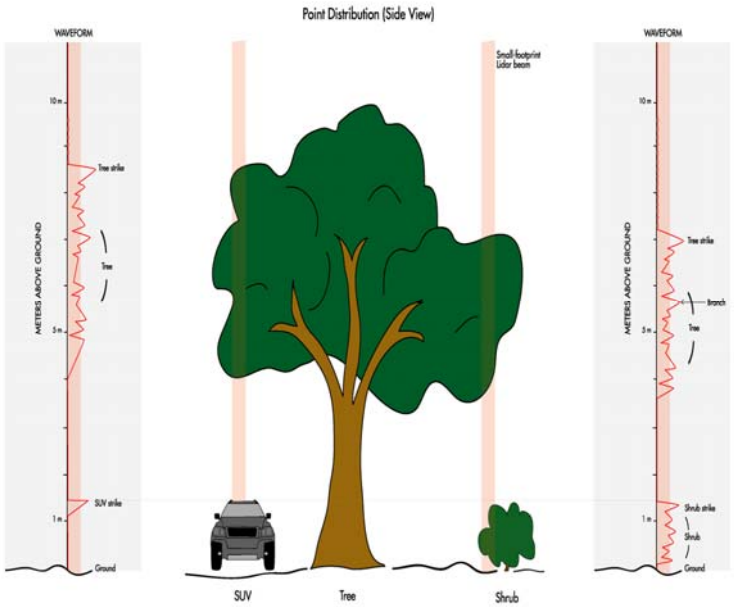
Platform Considerations

- *Fixed Wing*
- *Helicopter*
- *UAV*

Multiple & Digitized Returns

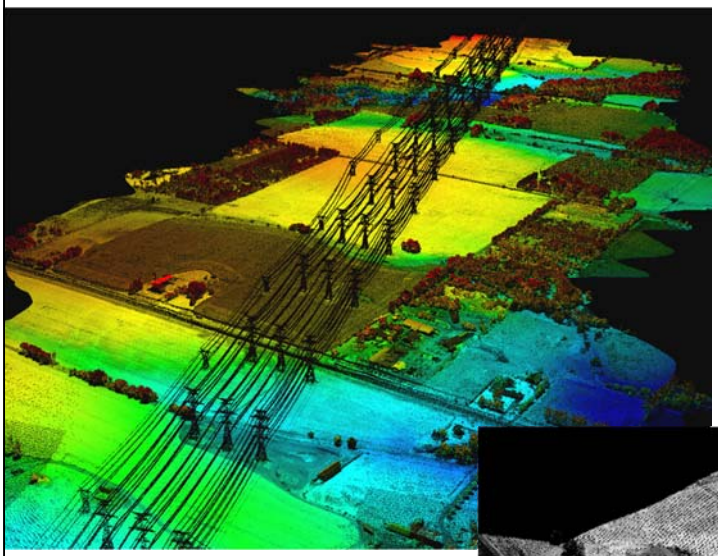


1st, 2nd, 3rd and last returns

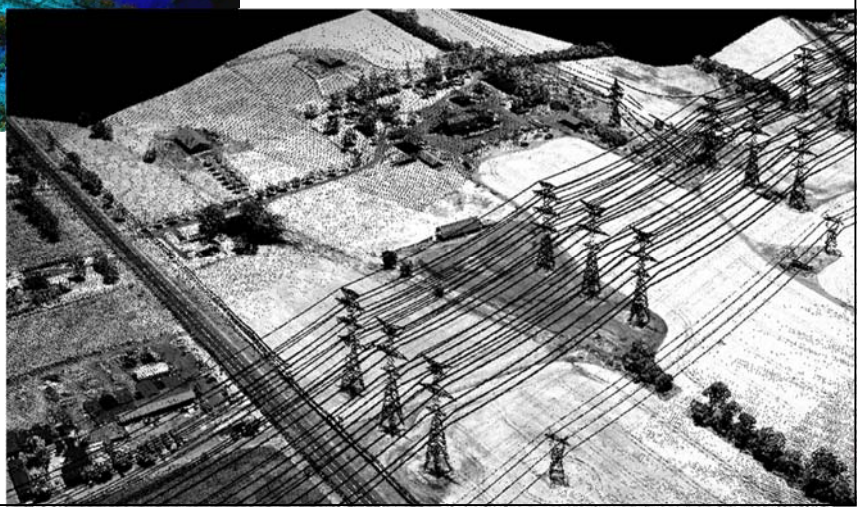


Fully digitized signal

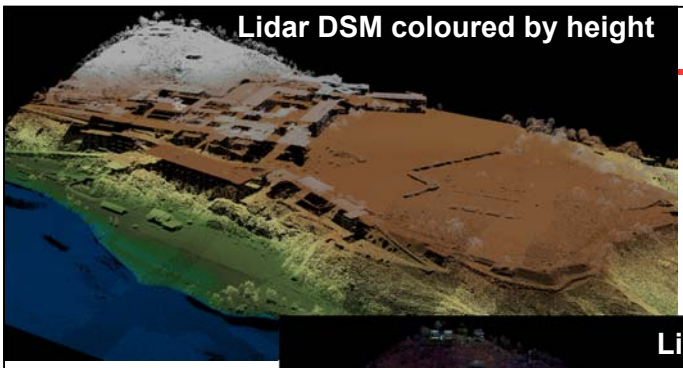
Lidar signal has 4 observables: X,Y,Z and Intensity



1-km AGL,
color-coded elevation data
includes conductors and
various ground features,
roads, structures, vegetation



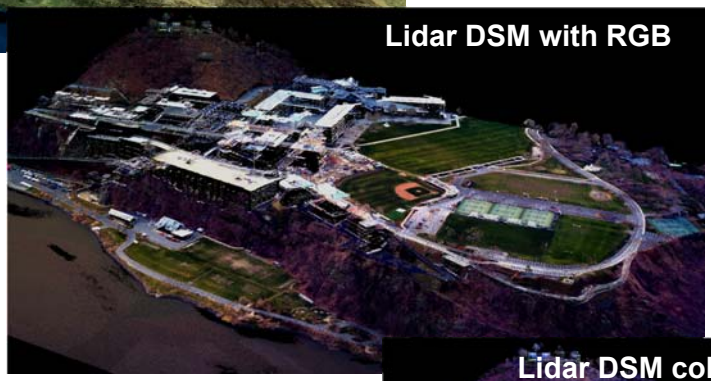
High quality grey-scale
intensity image
provides complementary
information for data analysis

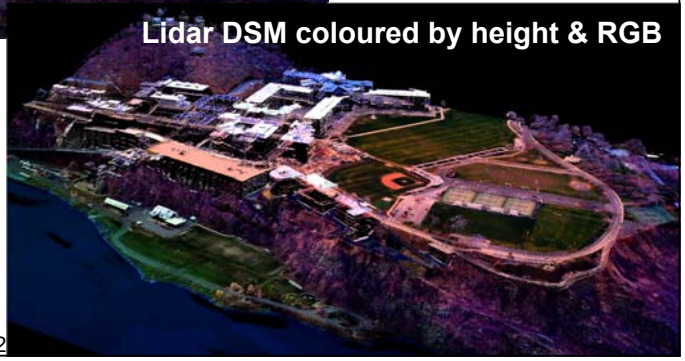


Sensor Synergy

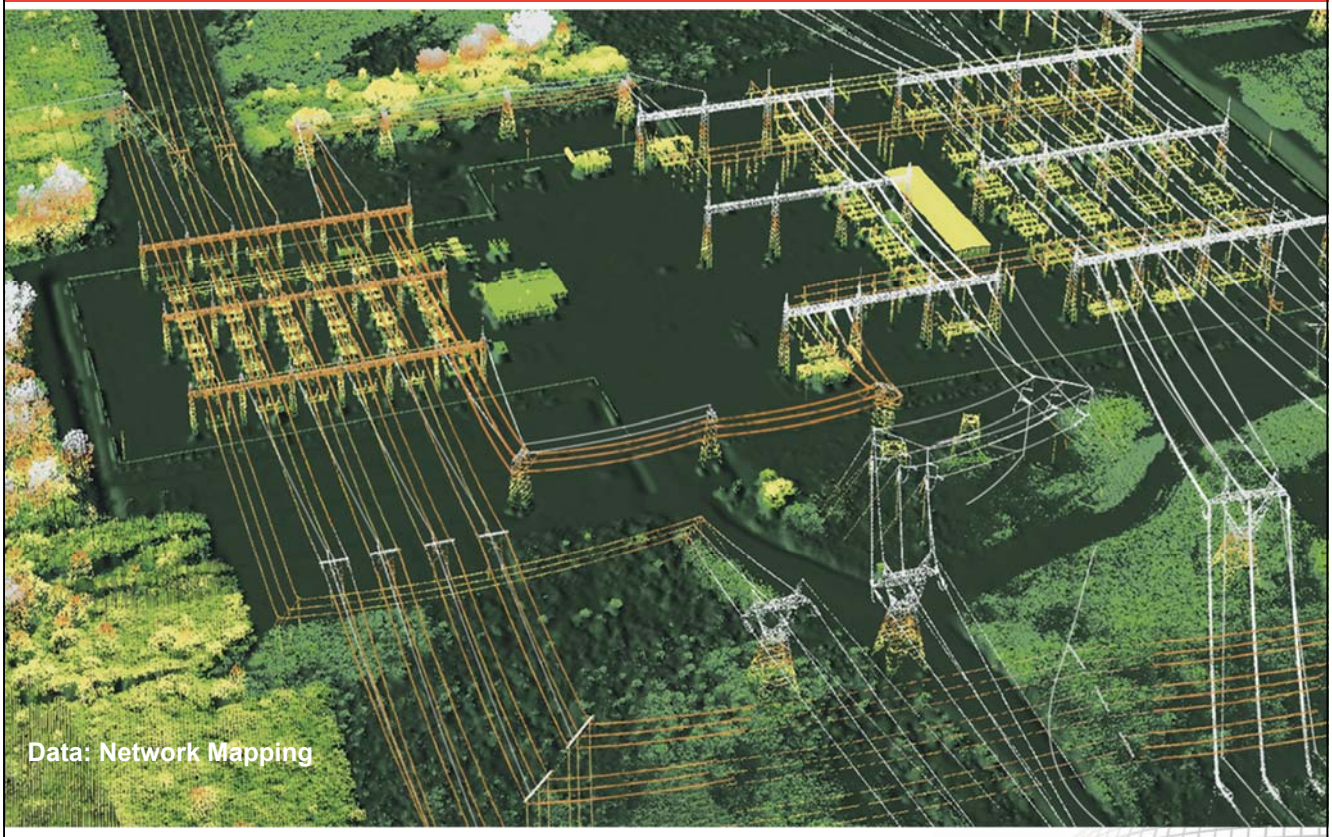
Passive / Active Data Fusion

Greatly enhances the information content

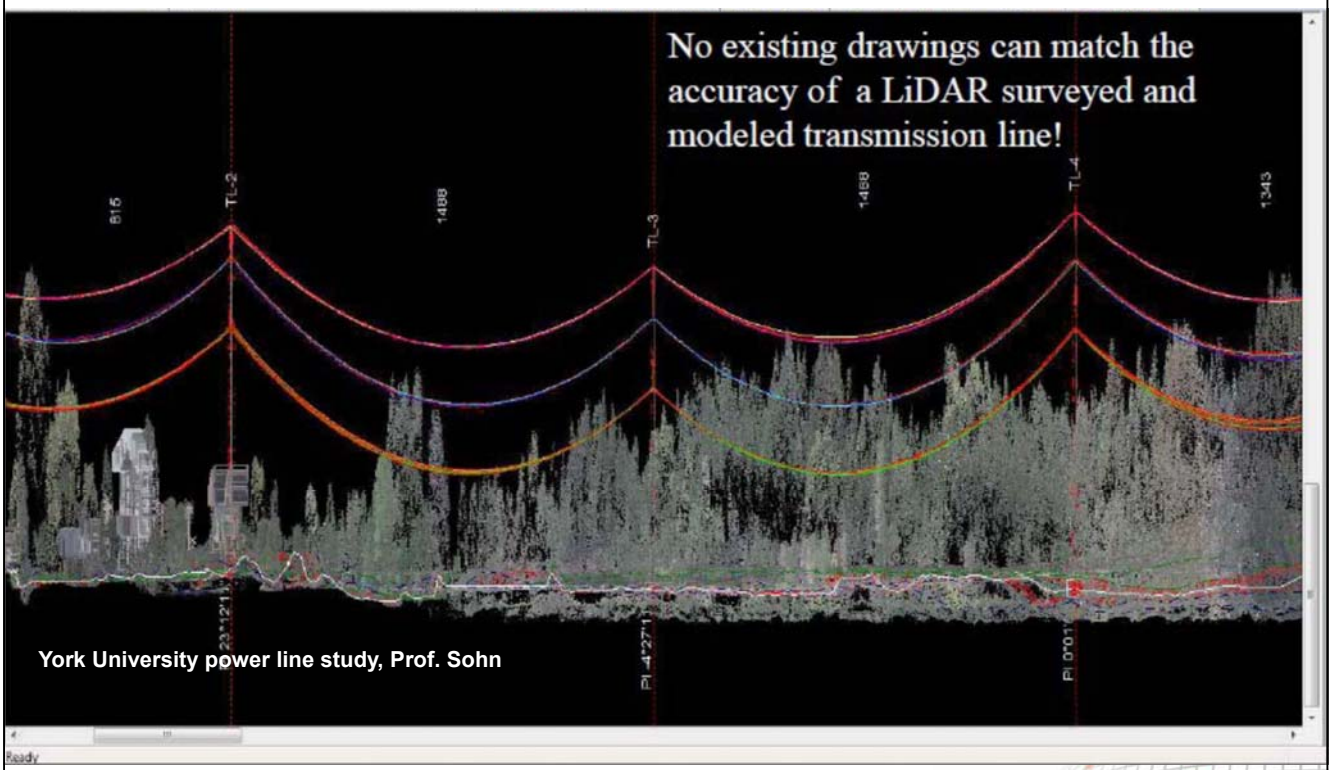




Power Line Asset Management & Corridor Mapping



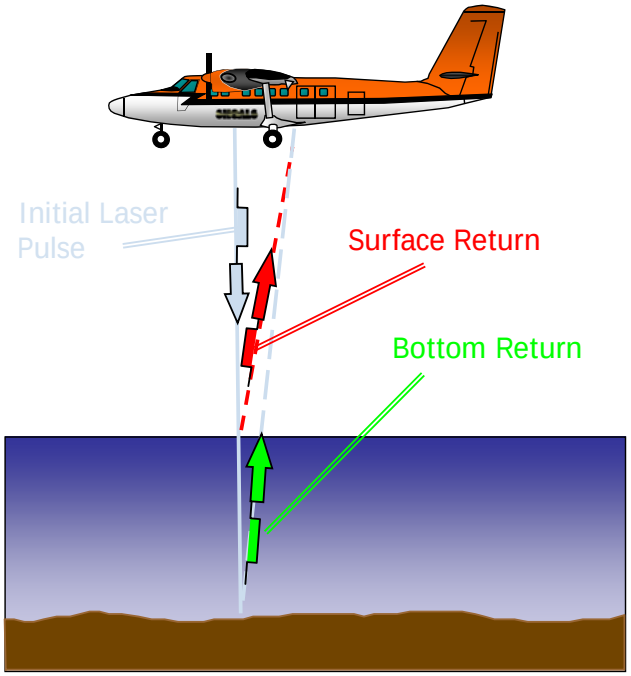
As-Designed vs As-Is Comparison



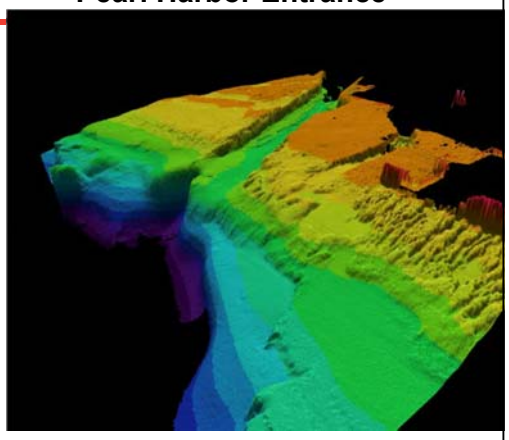
Airborne Marine Systems

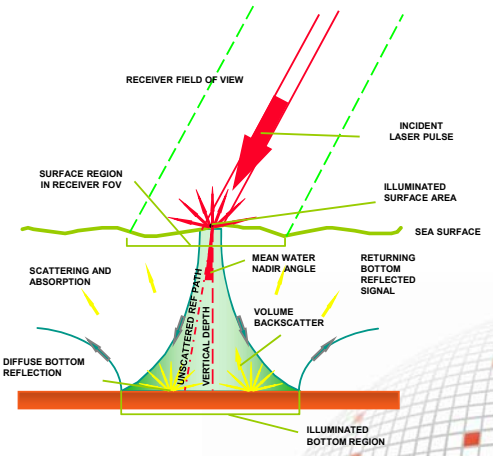
SHOALS

Scanning Hydrographic Operational Airborne Laser Survey



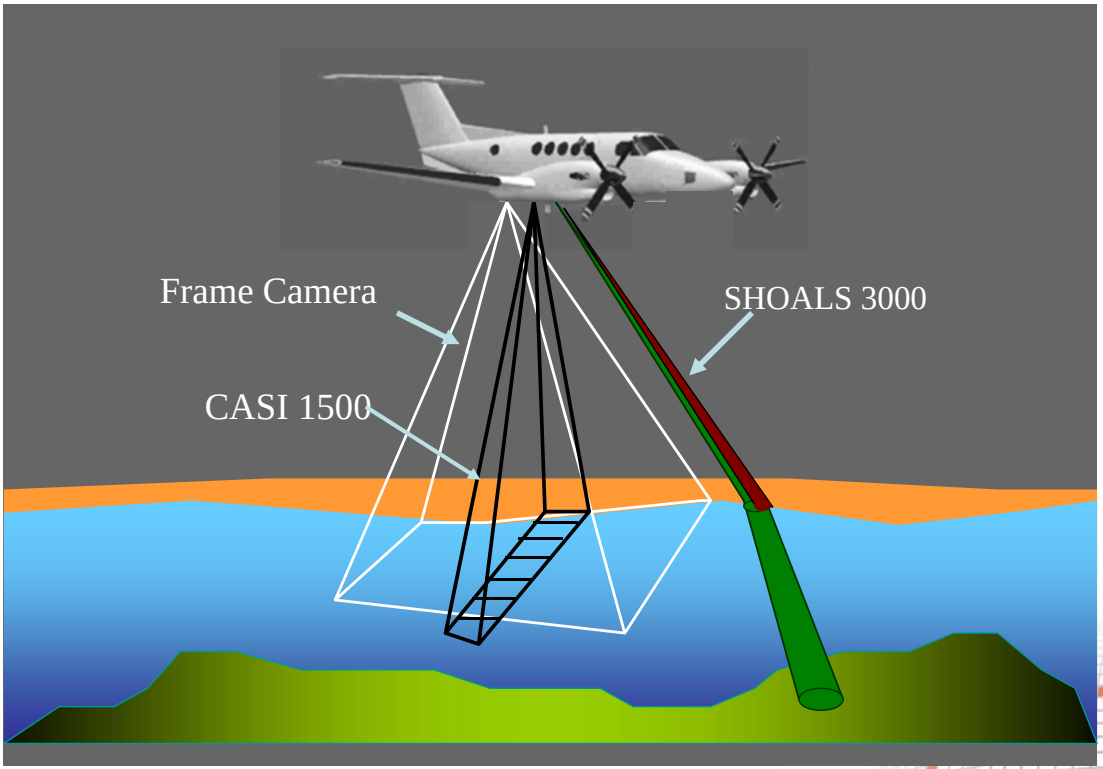
Pearl Harbor Entrance





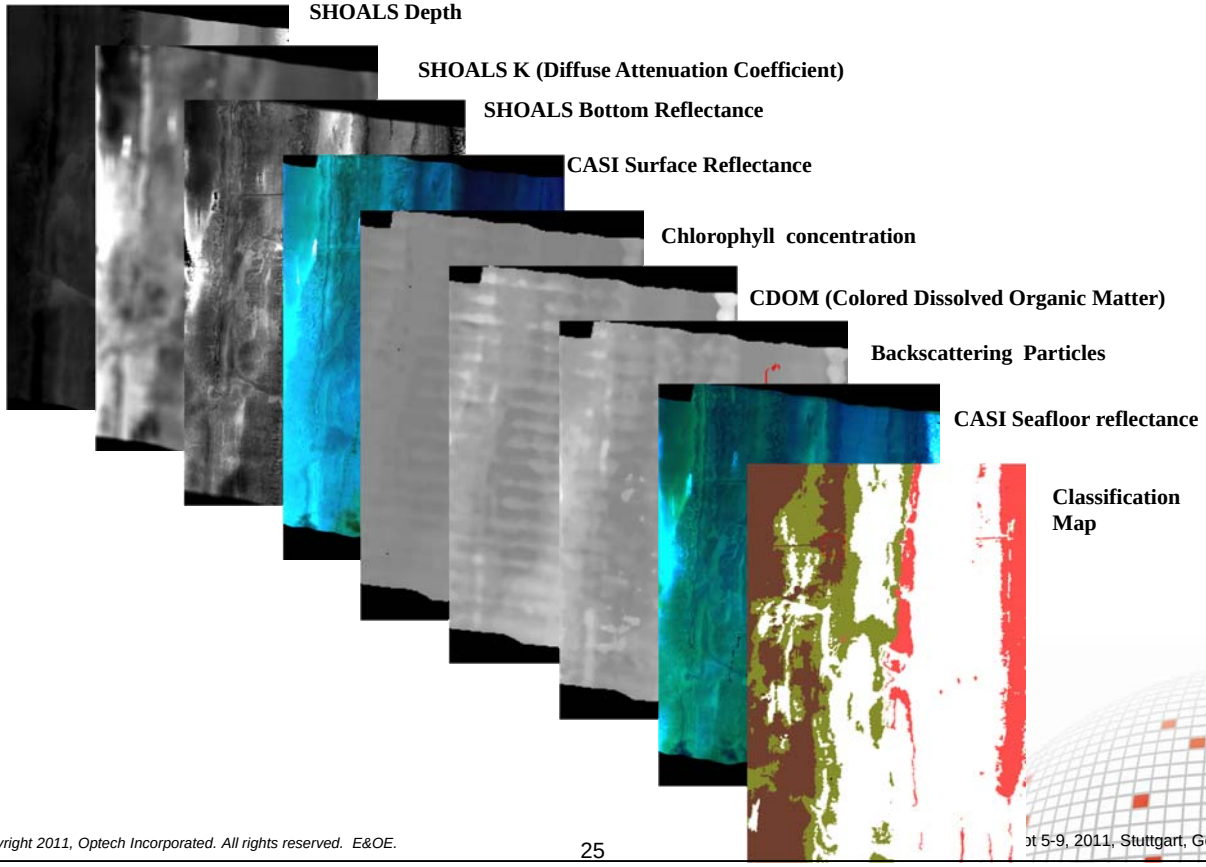
SHOALS/Hyperspectral

Active/Passive Data Fusion



Rapid Environmental Assessment (REA)

Software Products from Active-Passive Data Fusion



Coastal Zone Mapping and Imaging Lidar

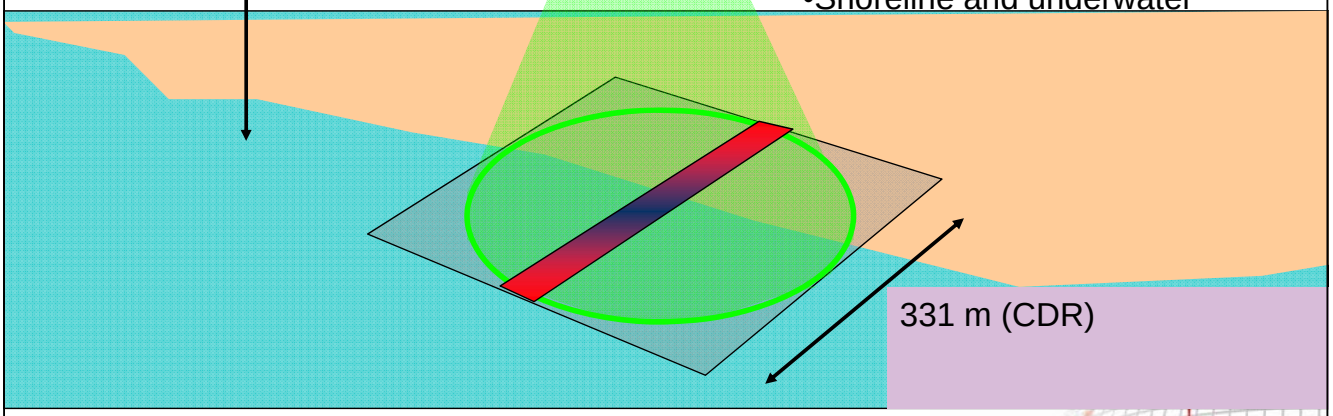
CZMIL

140 kts

400 m

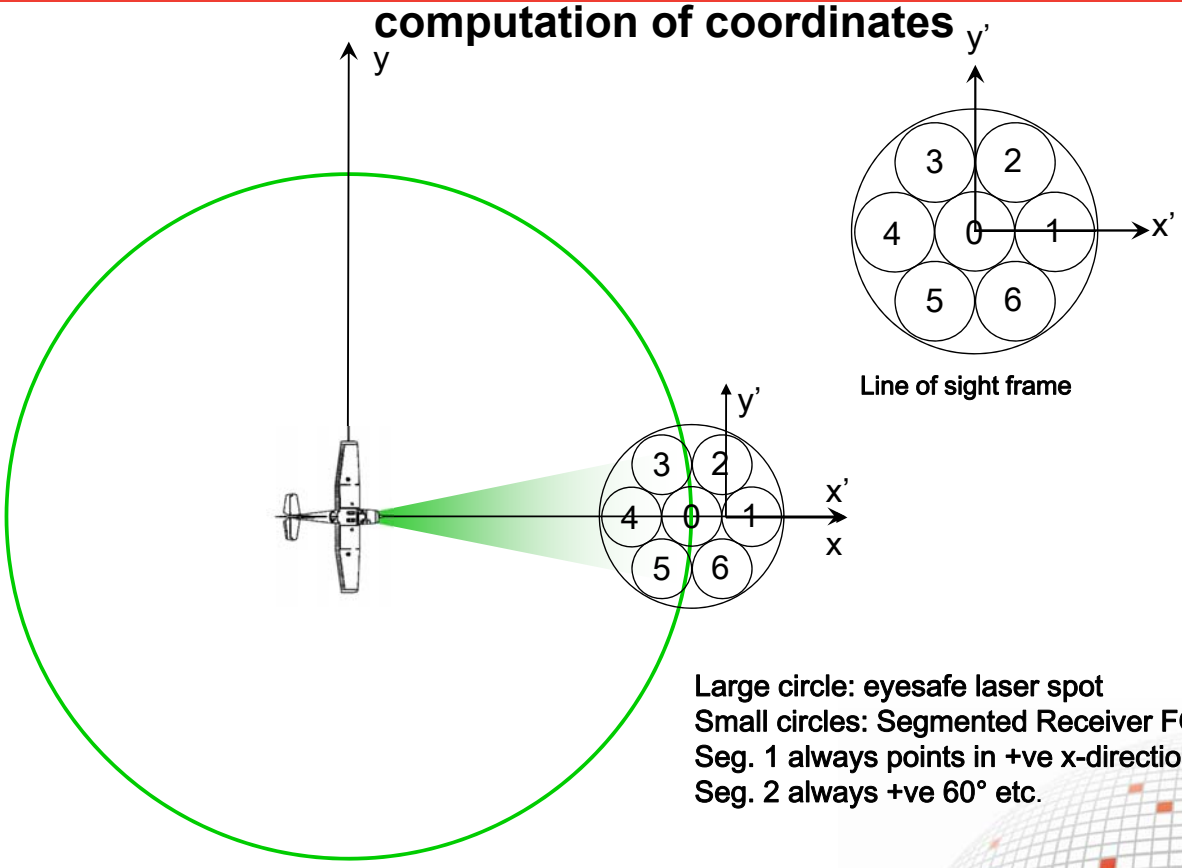
Improved hyperspectral lidar

- Higher rep rate (10kHz)
- Hybrid Lidar concept
- Segmented detector
- Better spatial resolution
- Shoreline and underwater



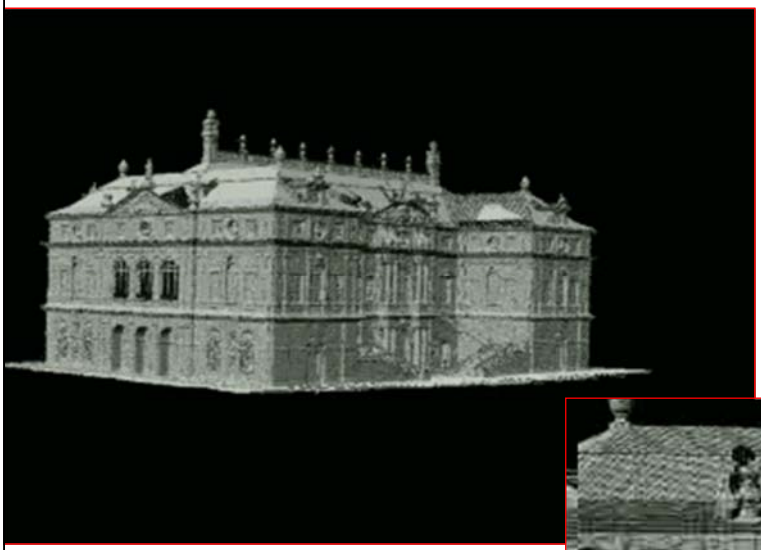
Hybrid lidar concept

computation of coordinates

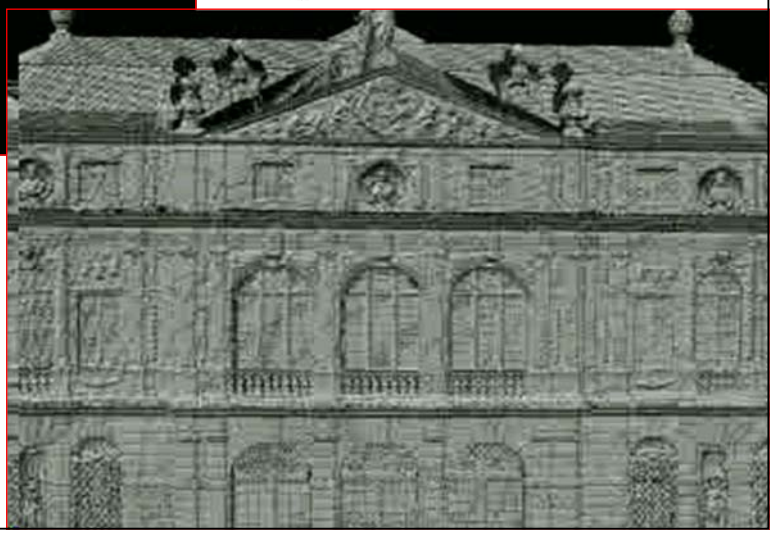


Large circle: eyesafe laser spot
Small circles: Segmented Receiver FOV
Seg. 1 always points in +ve x-direction
Seg. 2 always +ve 60° etc.

Tripod Mounted Systems



Intelligent
Laser
Range
Imaging
System

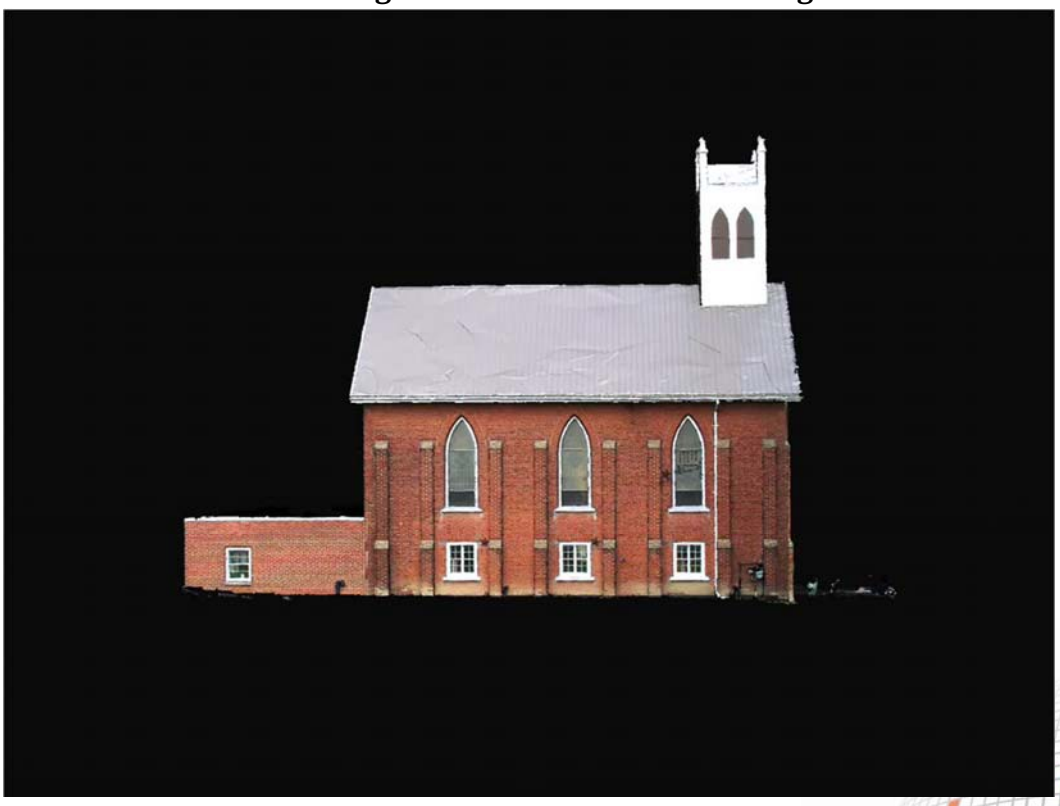


TopScan data
Old Palais, Dresden

Measurements to 2+ km range
Better than 1 cm resolution
Up to 360 degree field-of-view
Up to 50,000 measurements per second

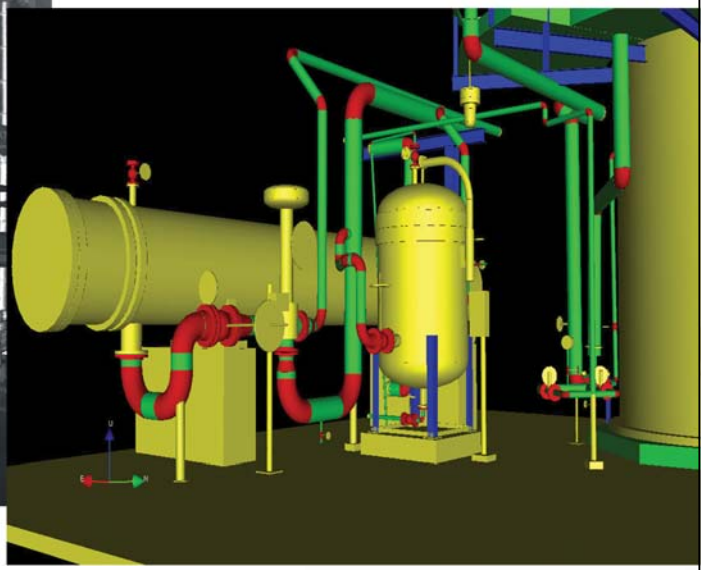
Lidar 3D Color Imagery

ILRIS point cloud merged with high resolution digital photo to generate a true 3D colour image.



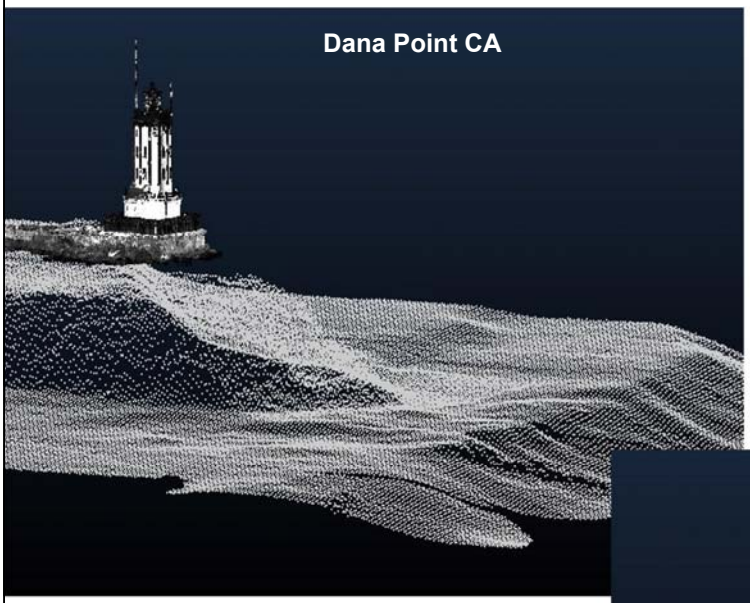
"As-Built" data sample

ILRIS Point Cloud



Derived solid model image

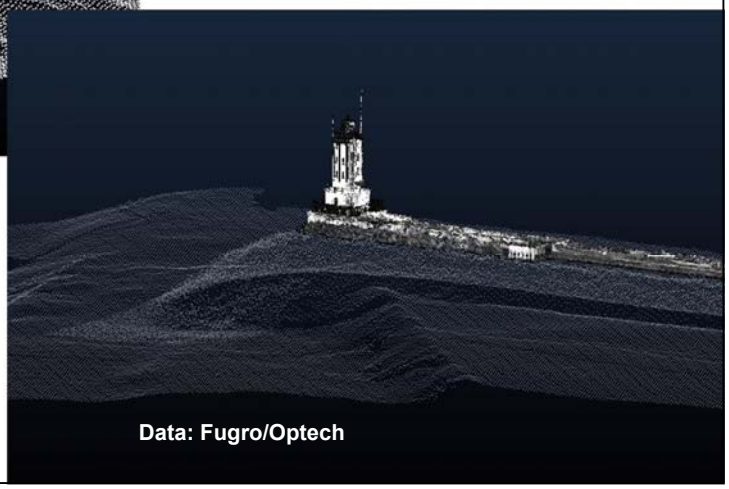
ILRIS Lidar Data Merged with Sonar Bathymetric Data



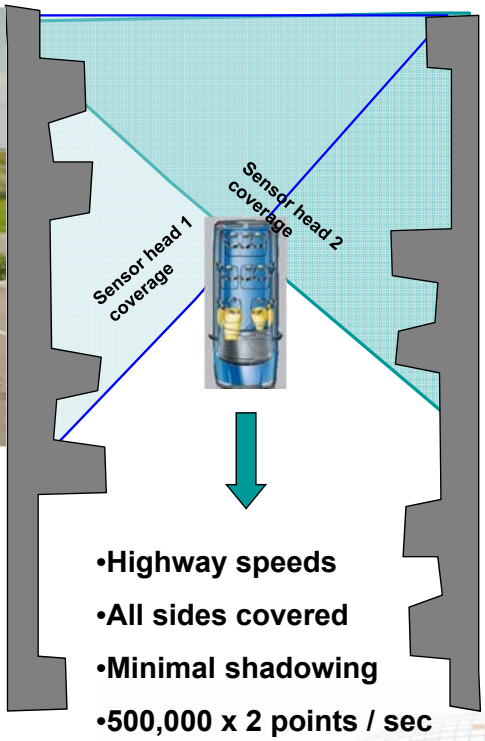
Static and boat-mounted ILRIS with motion compensation for surface measurements.(~1 to 2cm)

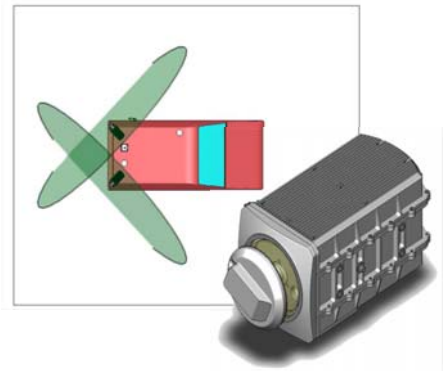
Interferometic multi-beam sonar for sub-surface measurements (10cm)

Complete 3D integrated georeferenced digital model of the areas above and below the water level.



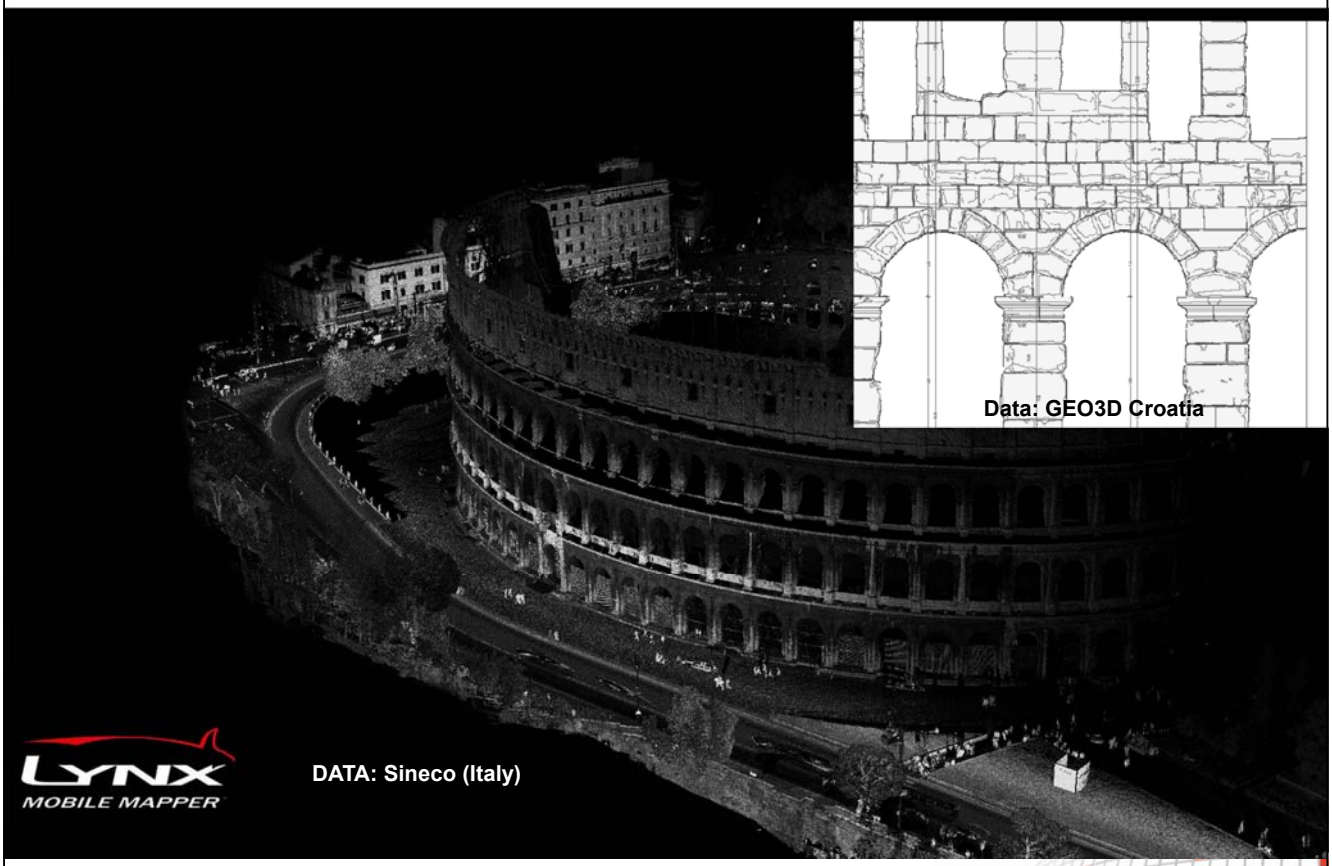
Mobile Mapping System



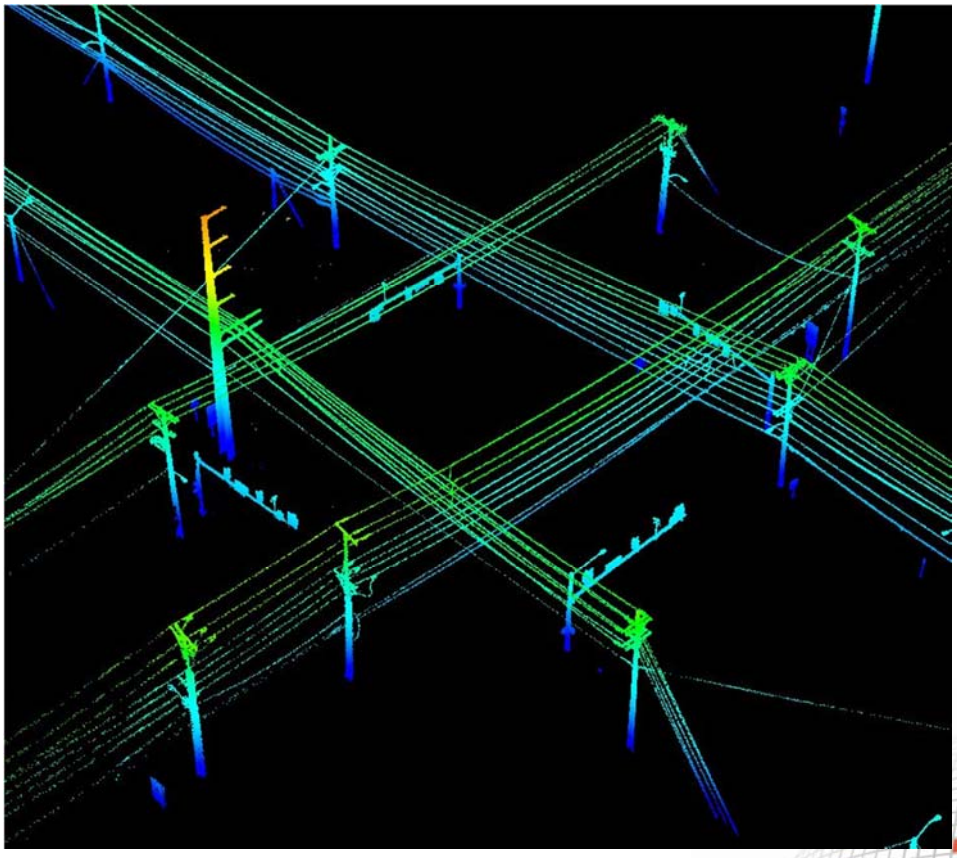


- **Highway speeds**
- **All sides covered**
- **Minimal shadowing**
- **500,000 x 2 points / sec**

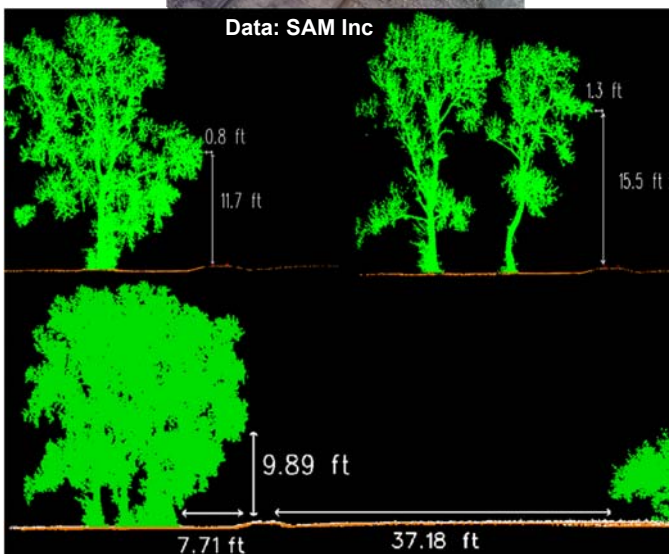
Coliseum in Rome



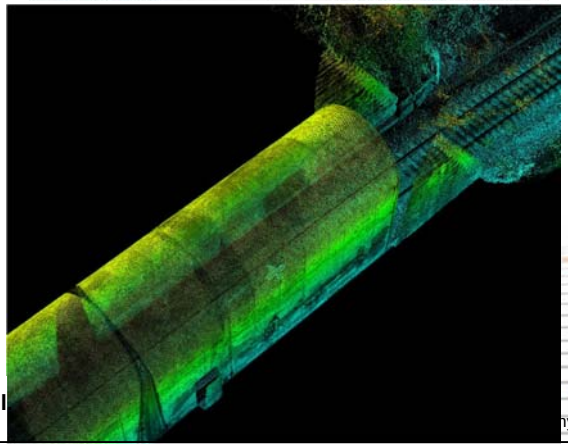
LYNX Intersection survey



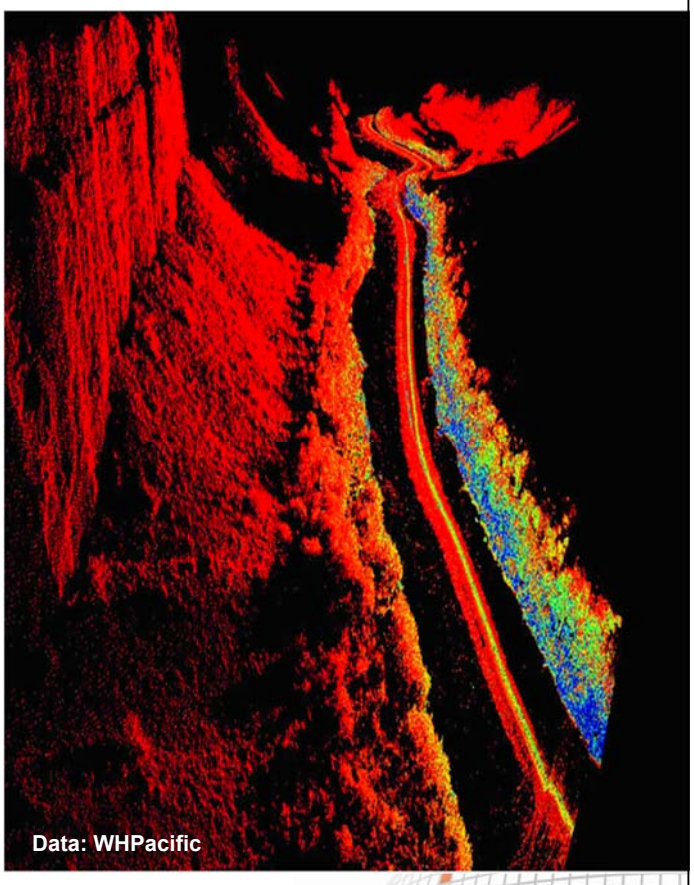
LYNX Rail and Tunnel Survey



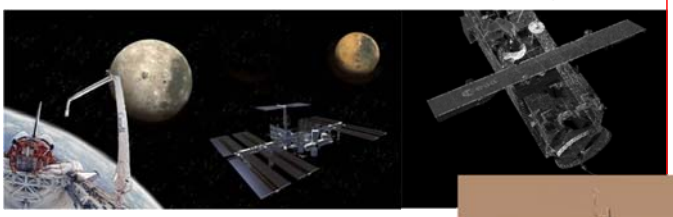
Tree heights above top of rail & distance of trunk from top center of rail



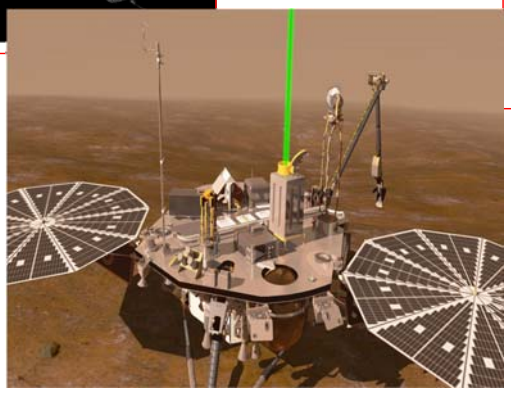
LYNX Snake River Survey



Space Lidar Systems

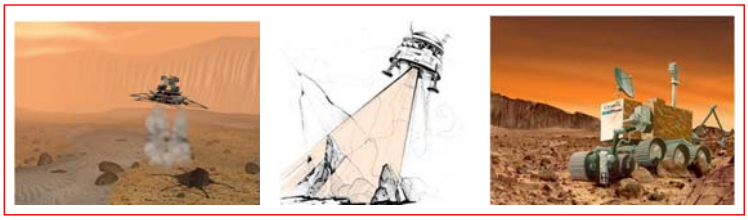


Rendezvous & Docking



Phoenix 2007 Mars mission

Earth Orbit systems

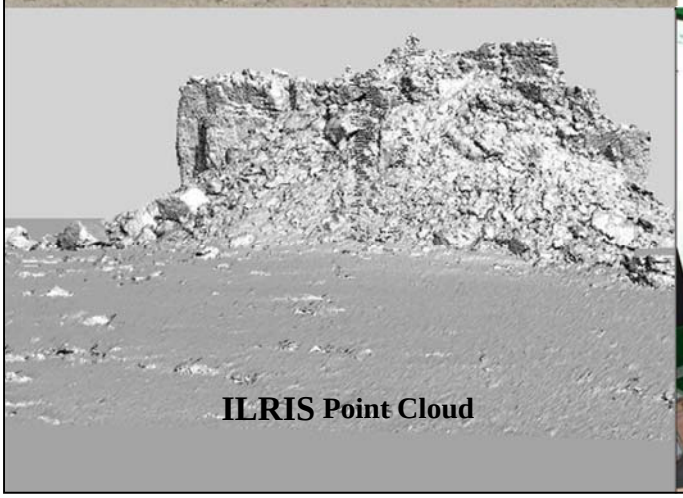


Smart Landers & Rovers

Inspection & Safety

Camera Image

NASA Robot Navigation & Site Survey
Haughton Crater, 2007



ILRIS Point Cloud

NASA Ames
control center

Lidar Imagery

An Exciting (Revolutionary?) and Highly Productive Future

- **Incorporation of the latest hardware & software advances.**
  - **A) Hardware:**
    - **Lasers: new, improved, different**
    - **Platforms: new configurations: surface, airborne, spaceborne**
    - **Electronics, computers, memories**
    - **Multi-sensors**
  - **B) Software:**
    - **Data selection & compression,**
    - **Enhanced data extraction tools**
    - **More sophisticated processing algorithms**
    - **Large data set management,**

- **Data Fusion among multiple sensors, Sensor Synergy (1+1 > 2)**

- **New & different ways of doing things**
  - **Increasing user lidar requirements & specifications**
  - **New system and analysis features focused on customer requirements**
  - **Improved efficiencies in processes**
  - **Data extraction, sharing, archiving**
  - **Changed work flows**
  - **Design-build interactions are changing to incorporate lidar capabilities**
  - **Establish performance specs, accuracy requirements, standards**
  - **Monitoring of construction phases**