Airborne Digital Data Capture Systems

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RACURS

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Outline & Structure of the Presentation

Part I – Airborne Digital Frame Cameras

(a) ***Single Cameras*** – with a Single Lens & Area Array
(i) Small-Format, (ii) Medium-Format & (iii) Large-Format Single Cameras. (iv) Stepping Frame Cameras.
(b) ***Multiple Cameras*** – with Multiple Lenses & Area Arrays
(i) Multi-Spectral; (ii) Multiple Obliques; (iii) Multiple Verticals.
(iv) Multiple Verticals & Obliques

Part II – Airborne Digital Line Scanners

(a) ***Single Line Scanners*** –
(i) Monochrome, (ii) Colour & (iii) Hyper-Spectral Line Scanners
(iv) Panoramic Line Scanners.
(b) ***Three-Line Stereo Line Scanners***

Outline & Structure of the Presentation

Part III – Airborne Radar Technologies

Part IV – Airborne Laser Scanners

(a) ***Airborne Topographic Laser Scanners***

(i) Commercial System Suppliers; (ii) Custom-Built Systems; &
(iii) Research Systems

(b) ***Airborne Bathymetric Laser Scanners***

(i) Commercial System Suppliers; (ii) Research Systems

Part I -Airborne Digital Frame Cameras

(a) Single Lens Cameras - (i) Small-Formats

Monochrome Cameras

Purpose-built for reconnaissance purposes

Fast framing rates; small formats; zoom lenses; folded optics

- -

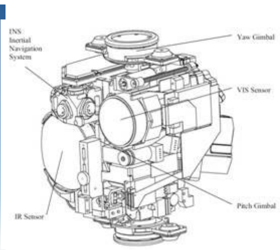
Example:-

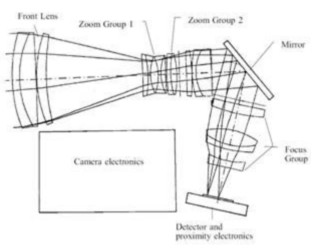
Carl Zeiss VOS40 Series

2k x 2k = 4 Mpix images

(i) ***VOS40/270*** – f = 270 mm lens; 15 frames per second

(ii) ***VOS40/500*** – f = 500 mm lens; 3 frames per second





Part I - Airborne Digital Frame Cameras

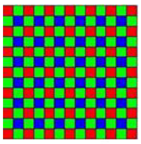
(a) Single Lens Cameras - (i) Small-Formats

Single Lens Cameras with Mosaic Filters & Bayer Interpolation – Providing Colour Images

(a) Cameras built in large numbers for use in **professional photography**; Comparatively inexpensive

(b) Formerly ***Kodak DCS 460/560/660/760*** series was much used – only 6 Mpix colour images

(c) Now ***Nikon D2X*** -12.4 Mpix ; ***Canon EOS-1Ds-II*** - 16.7 Mpix)



Canon EOD-1DsII 16.7 Mpix image

Nikon D2X 12.4 Mpix image

Bayer Interpolation using a mosaic filter. Each pixel receives light in one colour only - the other two colour values for that pixel are interpolated from the neighbouring pixels.
The resulting colour image has some small limitations in colour rendition!

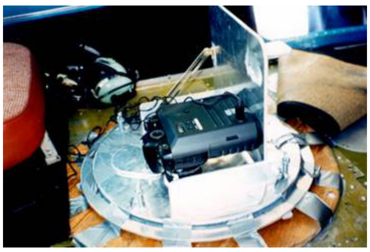
Part I - Airborne Digital Frame Cameras

(a) Single Lens Cameras - (i) Small-Formats

Many have been adapted for use in ***airborne imaging*** – add mount; shock absorbers; control box; GPS (+IMU).

Fitted to small aircraft and helicopters

Widely used - excellent for local projects -
(i) repeated flights for monitoring;
(ii) quick response to disasters



Part I -Airborne Digital Frame Cameras

(a) Single Lens Cameras - (i) Small-Formats

Digital Video Cameras
Now very much used from airborne platforms – especially for monitoring

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i) ***Standard Video Cameras***
Small-Format – NTSC/PAL

(ii) ***HDTV Cameras***
Much larger formats – 1920 x 1020 pixels [2 Mpix] @ 50/60 Hz

(iii) ***Ultra HDTV Cameras***
Still larger formats – up to 4520 x 2540 pixels [11 Mpix] @ 50/60 Hz - are now in development – see Red One

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Photogrammetrists now need to be more aware of these cameras and their images!

Sony Handycam

Adimec

Red One

Part I - Airborne Digital Frame Cameras

(a) Single Lens Cameras - (i) Small-Formats

Digital Video Cameras

(a) In an airborne context, digital video cameras are usually operated on a gyro-stabilized mount

(b) The cameras are mainly used for surveillance operations from helicopters, UAVs, blimps and STOL aircraft for continuous observation and monitoring purposes

Predator UAV

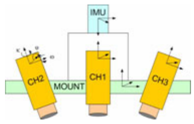
av8pix Blimp

Diamond DA42 MPP

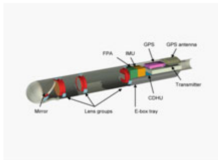
Part I - Airborne Digital Frame Cameras
(a) **Single Lens Cameras** (i) **Small-Formats**

Much current interest in cameras with **rectangular formats**

1. ***GeoPIE Project***
(VTT + Inpho + ICC)
"**New Metric Camera**"
10k x 1.6k format;
Optical butted CCDs



2. ***VITO (Belgium)***
"**Medusa**" System for **Mercator-1** UAV
10k x 1.2k format; f = 330 mm; H = 18 km;
Custom CMOS Chip



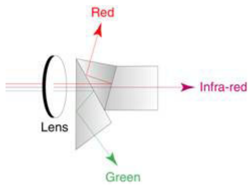
3. ***Global Imaging Technologies (USA)***
(i) G-2010 Series - 7.9k x 1.2k format; 5 CCDs
(ii) ARDIS-II Series – 7k x 1k format; 5 CCDs

(i)

(ii)

Part I - Airborne Digital Frame Cameras
(a) **Single Lens Cameras - (i) Small-Formats**

Single Lens Cameras with Beam Splitters
These produce three multi-band images from which colour images can be produced – so no interpolation is needed



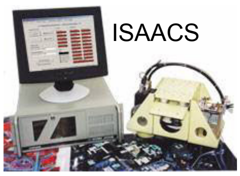
(a) Single Supplier – **Redlake -** only very small formats are available –
(i) ***MS3100*** (1k x 1.4k) and
(ii) ***MS4100*** (1k x 1.9k)

MS4100

(b) Used as basis for airborne systems by various suppliers
(i) ***Airborne Data Systems*** (U.S.A.) – ***AgriView***
(ii) ***Integrated Spectronics*** (Australia) - ***ISAACS***

AgriView

ISAACS



Part I - Airborne Digital Frame Cameras

(a) **Single Lens Cameras - (ii) Medium-Formats**

Single Cameras – Modified Film Cameras

(a) Based on well-known medium-format ***professional film cameras*** from Hasselblad, Rollei, Contax

(b) The film magazines are replaced by ***digital backs*** from MegaVision (USA); PhaseOne (DK); Imacon (Sweden)

(c) (i) Most first used the ***Kodak*** 4k x 4k = 16 Mpix CCD array;
(ii) later the ***Kodak*** 5.4k x 4k = 22 Mpix array;
(iii) now there are the newly introduced 31.6 and 39 Mpix arrays

(d) Examples:-
(i) ***Applanix DSS*** (Digital Sensor System) – uses **Contax** camera with MegaVision digital back + POS/AV (DGPS/IMU) unit
(ii) ***Rollei AIC*** uses **Rolleimetric** camera with Phase One back
(iii) ***IGI DigiCAM*** uses **Hassleblad** camera with Imacon back

Part I - Airborne Digital Frame Cameras

(a) **Single Lens Cameras - (ii) Medium-Formats**

This **H 25** digital back from **Phase One (Denmark)** is based on a Kodak CCD area array with 22 Mpix

The colour image is obtained using a mosaic filter and Bayer interpolation

It has been fitted, for example, to this Rollei camera as a replacement of the film magazine

These digital backs generate colour images through the use of **mosaic filters** and **Bayer interpolation**

Part I - Airborne Digital Frame Cameras

(a) **Single Lens Cameras - (ii) Medium-Formats**

Applanix DSS camera & POS/DG control box + screen

IGI DigiCAM digital back, body & lens

Rollei AIC camera & digital back

Somag SSM150 mount

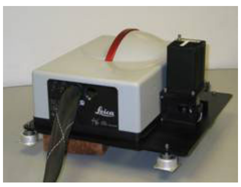
GGS AeroStab-2 stabilized mount

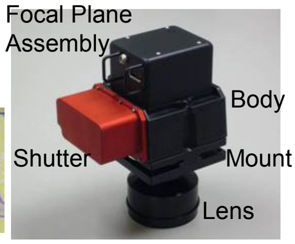
Part I - Airborne Digital Frame Cameras

(a) Single Lens Cameras - (ii) Medium-Formats

Many of these medium-format digital frame cameras are being used in conjunction with airborne laser scanners – e.g. **Optech ALTM** with **Rollei AIC** (left) and **Applanix DSS** (right)

Leica has also integrated various medium-format cameras with its **ALS50** laser scanners – e.g. Spectrum NexVue (left). Now it has its own newly introduced **RCD105** camera with 39 Mpix colour back.





Part I - Airborne Digital Frame Cameras

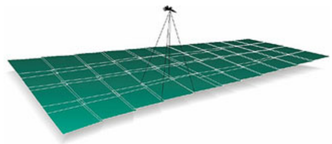
(a) Single Lens Cameras – (iii) Large Formats

(ii) ***BAE Systems*** –
F-979F & F-985F models
– 9k x 9k = 85 Mpix

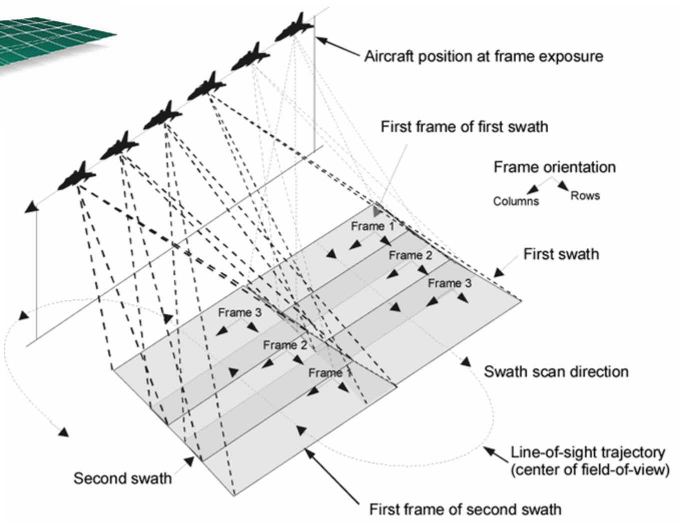
Clockwise from top left
– camera; electronics unit;
9k x 9k CCD area array;
& focal plane shutter

Part I - Airborne Digital Frame Cameras

(a) Single Lens Cameras – (iv) Stepping Frames



A sequence of frames is exposed **cross-track** at a very high speed to provide a **very wide angular coverage** of the ground



Part I - Airborne Digital Frame Cameras

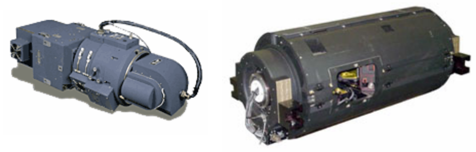
(a) Single Lens Cameras – (iv) Stepping Frames

(i) VisionMap (Israel)

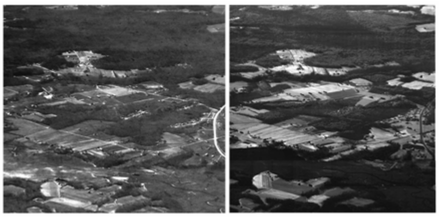
Twin 11 Mpix pan photos side-by-side in a single cross-track scan

(ii) ***Recon Optical*** *(USA)*

CA-260/270/295 series – 25 & 50 Mpix



Twin pan + IR photos generated side-by-side in a single cross-track scan



Part I - Airborne Digital Frame Cameras

(b) ***Multiple Cameras*** – with Multiple Lenses & Arrays

(i) Multi-Spectral Cameras;

(ii) Multiple Oblique Cameras;

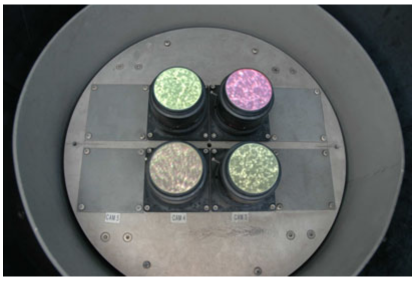
(iii) Multiple Integrated Types.

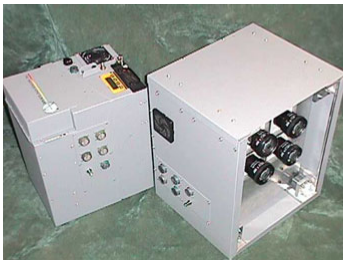
Part I - Airborne Digital Frame Cameras

(b) Multiple Cameras (i) Multi-Spectral

Example:-

The **SpectraView** imager from ***Airborne Data Systems*** achieves colour and false colour images by means of four **small-format** digital frame cameras in a rigid mount, each camera having a different filter – the four images are then merged



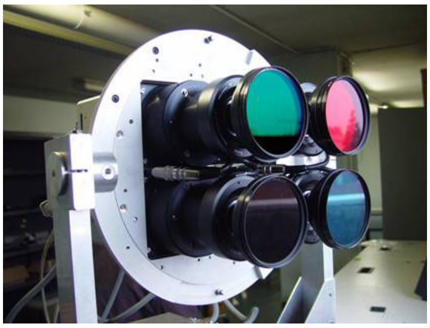


Part III - Airborne Digital Frame Cameras

(b) Multiple Cameras (i) Multi-Spectral

Multi-Spectral – Medium-Format

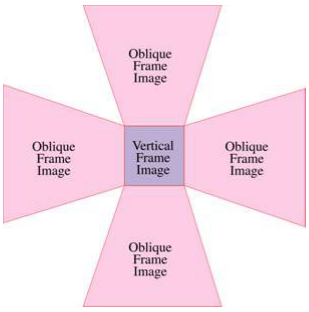
IGN (France) uses four Kodak **medium-format** 4k x 4k = 16 Mpix cameras + spectral filters to form the basis for its ***Quadricom*** multi-band camera system. No interpolation needed for the colour images



Similar to small-format multi-camera / multi-band systems but with a much larger format.

Part I - Airborne Digital Frame Cameras
(b) Multiple Cameras – (ii) Multiple Obliques

Use of three (1 vertical + 2 oblique) or five (I vertical + 4 oblique) small-format cameras having **mosaic filters**. Specially built mounts

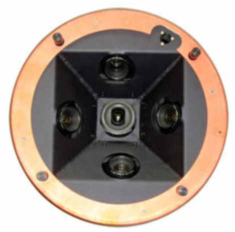


5-Camera Coverage

Oblique image of part of the Las Vegas Strip acquired by Pictometry International; the side views of the buildings indicate the information available from obliques, which are popular with emergency services, defense and homeland security agencies

Part I - Airborne Digital Frame Cameras
(b) Multiple Cameras – (ii) Multiple Obliques

MIDAS oblique 5-camera system built by Track'Air (Netherlands)



5 Canon small-format cameras give 5 x 16.7 Mpix = 83.5 Mpix per exposure – same as a large-format camera !!

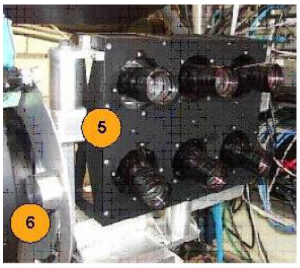
Part I - Airborne Digital Frame Cameras

(b) Multiple Cameras – (ii) Multiple Obliques

ITT/Geospatial System

Airborne Persistent Surveillance System

"Six-Pack" Cameras



5 = Camera system
6 = Cradle points system to a GPS ground location

GPS, Camera Control & Image Data Storage

The six GSI 11 Mpix metric cameras produce a 66 Mpix area coverage of the ground. The image data is processed and compressed on-board the platform and is sent continuously via a radio link to a ground station at 48 Mbps.

Part I - Airborne Digital Frame Cameras

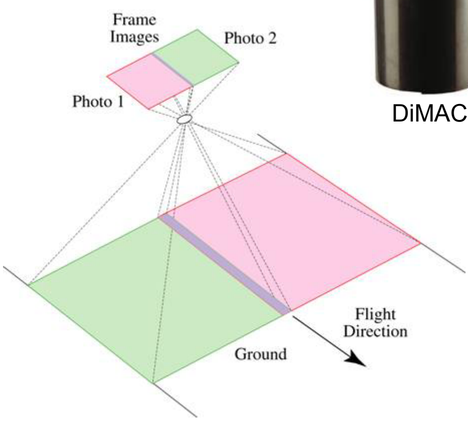
(b) Multiple Cameras – (iii) Multiple Verticals

DiMAC Systems

(i) Originally had 4 ***oblique*** cameras, each with 22 Mpix digital backs.

(ii) Now 2 ***vertical*** cameras, each with offset position of the digital backs to give images to left and right of the flight line.

(iii) Each camera has a 39 Mpix digital back from Phase One, giving 75.6 Mpix colour image when merged.



DiMAC-2

Part I - Airborne Digital Frame Cameras

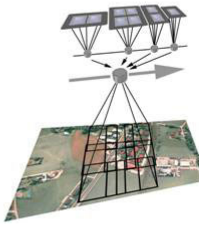
(b) Multiple Cameras – (iii) Integrated Multi-Vertical

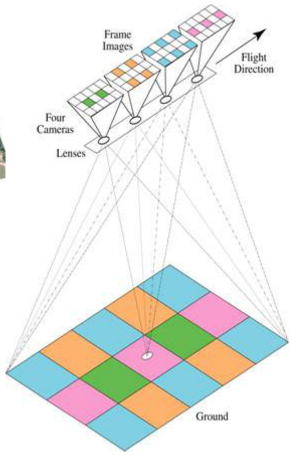
Vexcel UltraCam D –

(i) 4 medium-format vertical cameras - 86 Mpix pan image;

(ii) 4 small-format vertical multi-band cameras for colour, each 2.6k x 4k = 11 Mpix

(iii) now ***UltraCam-X*** – (i) 133Mpix pan; and (ii) 5 x 3.3k = 16.5 Mpix for each colour





Vexcel patent – with 15 arrays!

Part I -Airborne Digital Frame Cameras

(b) Multiple Cameras – (iii) Integrated Multi-Vertical

Vexcel UltraCam-D

The interior of an Antonov An-30 photographic aircraft being operated by the Russian Geokosmos mapping company – showing its **Vexcel UltraCam D** large-format digital camera, together with a pair of **Rollei AIC** medium-format digital cameras and an **Optech ALTM** laser scanner

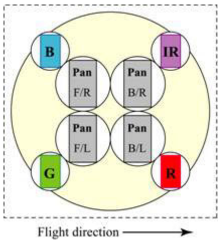
Part I - Airborne Digital Frame Cameras

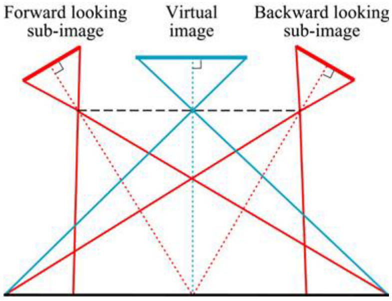
(b) Multiple Cameras – (iv) Integrated Vert. & Oblique

Intergraph DMC

(i) 4 oblique cameras with the tilted images rectified and merged to form 108 Mpix pan images

(ii) 4 small-format vertical cameras for colour, each 2k x 3k = 6 Mpix covering a different spectral band





DMC with Solid State Disk

FDS High Density Disks

Part II – Airborne Digital Line Scanners

(a) *Single Line Scanners*

- **(i) Monochrome Line Scanners**
- **(iii) Colour Line Scanners**
- **(iv) Hyperspectral Line Scanners**
- **(v) Panoramic Line Scanners**

(b) *Three-Line Stereo Line Scanners*

(i) Inertial Measuring Units (IMUs)

(ii) Differential GPS

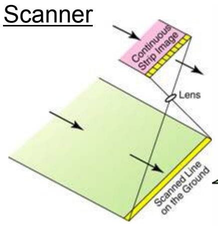
Part II -Airborne Digital Line Scanners

All of these imagers use **linear arrays** with a scan operation.
Each individual line in the image has a different **position** and **attitude (tilt)** value at its time of exposure

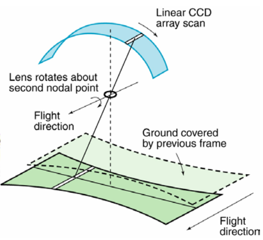
These values need to be measured using a **DGPS/IMU system** – which adds considerably to the overall cost of the system

Large changes in the aircraft heading or tilts result in **gaps** or **double imaging** – so a fast-acting **gyro-stabilized mount** is also obligatory.

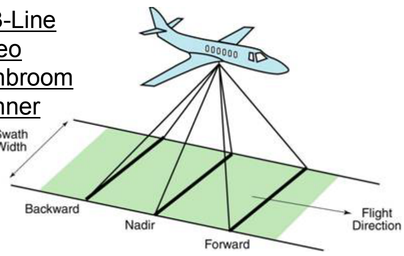
(i) Simple Pushbroom Scanner



(ii) Panoramic Line Scanner



(iii) 3-Line Stereo Pushbroom Scanner



Part II - Airborne Digital Line Scanners

(a) Single Line Scanners – (i) Monochrome Scanners

Mainly used for military recce purposes – **monochrome** images only.

(a) ***Thales Optonics (Vinten)***

(i) ***Model 8010*** – 4k linear array Range of lenses for low-altitude operation. Roll-corrected, not fully stabilized.

(ii) ***Model 8042*** – 12k linear array + f = 45cm lens for high-altitude operations.
Scanner usually mounted in a pod under the aircraft.

(b) ***Global Scan (France)*** – 6k linear array + range of lenses. Low-altitude operation.

(i)

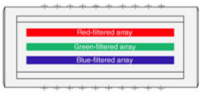
(ii)

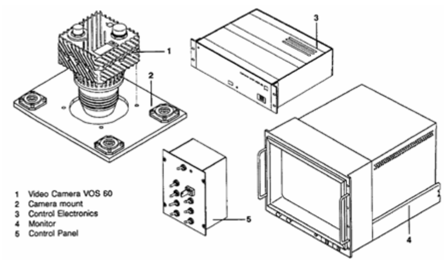
Part II - Airborne Digital Line Scanners

(a) Single Line Scanners – (ii) Colour Scanners

These pushbroom scanners produce continuous linescan images in colour (instead of monochrome) using a tri-linear CCD array.

(i) Examples are the **Zeiss VOS-60** and **VOS-80 scanners** with f = 60 and f = 80 mm lenses using tri-linear arrays with 3 x 6000 detectors.





(ii) The new **Verimap** scanner is similar but uses a tri-linear RGB array with 3 x 14,400 pixels + an NIR array

Part II - Airborne Digital Line Scanners

(a) Single Line Scanners – (iii) Hyperspectral Scanners

(i) ***Hyperspectral pushbroom line scanners*** use a CCD area array – which is however operated in a pushbroom mode as with a linear array.

(ii) The remaining detectors in the area array collect the spectral (colour) data for that line in hundreds of narrow spectral channels.

(iii) The spectral data is generated using a dispersive prism or grating – that acts as an imaging spectrometer.

(iv) The final result is an image "cube".

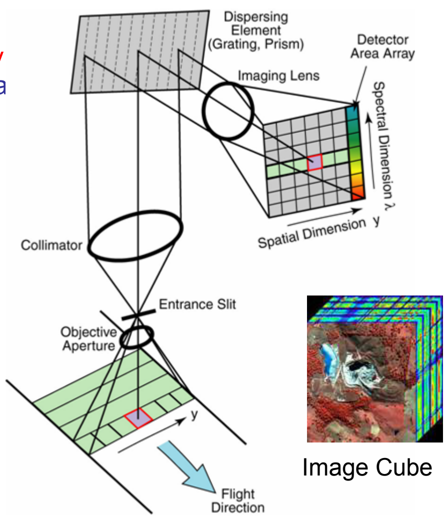


Image Cube

Part II - Airborne Digital Line Scanners

(a) Single Line Scanners – (iii) Hyperspectral Scanners

Three main suppliers of hyperspectral pushbroom and whiskbroom line scanners:-

(1) ***ITRES Research (Canada)***

(i) CASI (VIS/NIR) – 1,500 pixel swath; 299 spectral channels

(ii) SASI (SWIR) – 640 pixel swath; 160 spectral channels

(2) ***SPECIM (Finland)***

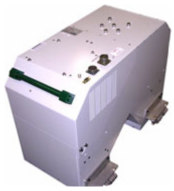
(i) AISA+ (VIS/NIR) - 500 pixel swath: 244 spectral channels

(ii) AISA Eagle (VIS/NIR) – 1,000 pixel swath; 244 spectral channels

(iii) AISA Hawk (SWIR) – 320 pixel swath; 254 spectral channels

(3) ***Integrated Spectronics (Australia)***

HyMap (VIS/SWIR) – 128 spectral channels

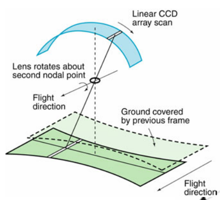


CASI AISA
(Pushbroom Scanners)

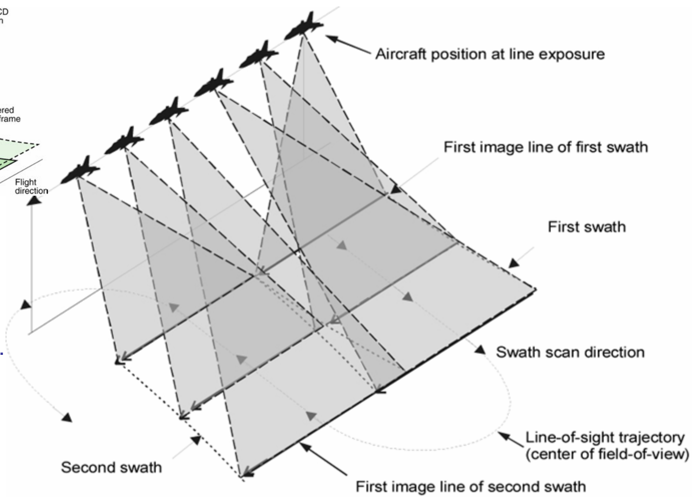
HyMap (Whiskbroom Scanner)

Part II - Airborne Digital Line Scanners

(a) Single Line Scanners – (iv) Panoramic Scanners



A linear array is used to scan cross-track to produce a **panoramic image**. Used by the military and by ImageAmerica (now owned by Google!)

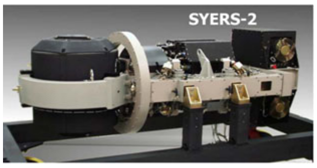


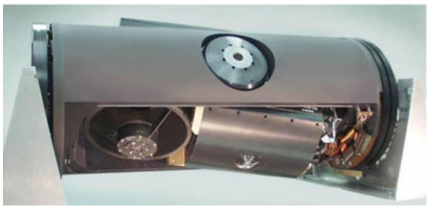
Part II - Airborne Digital Line Scanners

(a) Single Line Scanners – (iv) Panoramic Scanners

Goodrich Panoramic Line Scanners

Goodrich have built many of these imagers for the U-2 (SYERS) and for the RAF, Polish & Greek Air Forces (DB-110/Raptor). Data is sent to a ground station via a radio link.

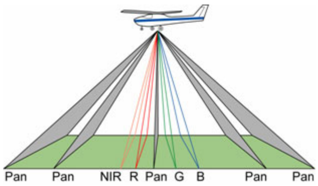




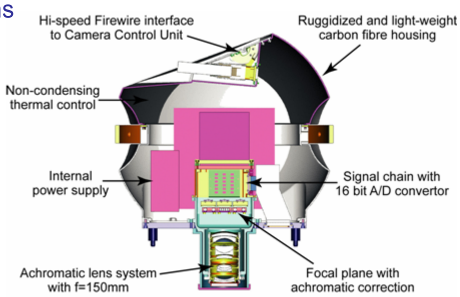
Part II - Airborne Digital Line Scanners

(b) Three-Line Stereo Line Scanners

In the late 1990s, **DLR** developed its HRSC-A airborne scanners based on its HRSC (Mars) space scanner. The **HRSC-AX** has nine 12k linear arrays (five pan + four RGB/NIR); f = 151mm lens



New **Jena-Optronik JAS-150** has similar specification and geometry to HRSC-AX, but with new lens and technology



Part II - Airborne Digital Line Scanners
(b) Three-Line Stereo Line Scanners

Leica Geosystems ADS40 scanner

Based partly on DLR WAAC pushbroom technology –

12k linear arrays - 3 for pan images, 4 for multi-spectral images; special telecentric lens; PAV30 gyro-stabilized mount; integrated DGPS/IMU

(i) The ADS40 has been adopted widely in **North America** by many major mapping companies.

(ii) A number have also been sold in **Europe** - including two in Russia operated by VISKHAGI for its LARIS cadastral project; and one in Estonia operated by its national mapping agency (MAA-AMET)


Russia


Estonia

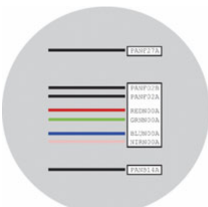

Italian ADS40 – CGR, Parma

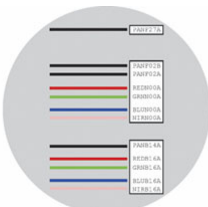
Part II - Airborne Digital Line Scanners
(b) Three-Line Stereo Line Scanners

Leica ADS40 2nd Generation – two alternative "sensor heads" –

(i) ***SH51*** has a single tetrachroid prism giving 5 spectral bands (Pan + RGB + NIR) in nadir position + two Pan forward & backward pointing lines.

(ii) ***SH52*** has two tetrachroid prisms – 1st in nadir position as in SH51; 2nd in backward pointing position; each with 5 spectral bands + one Pan forward pointing line.

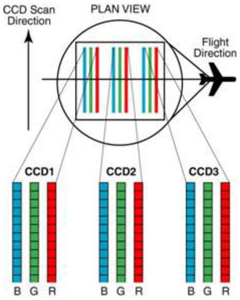

SH51


SH52


New IPAS10 DGPS/IMU unit developed in-house

Part II - Airborne Digital Line Scanners
(b) Three-Line Stereo Line Scanners

Wehrli Associates (U.S.A.) & Geosystems (Ukraine)



2 models, both built in the **Ukraine**. Each uses three Kodak Tri-linear arrays + three lenses

(i) ***3-DAS-1*** with 26° forward, nadir and 16° backward pointings;

(ii) ***3-OC*** with nadir plus 45° forward/backward pointings – designed to produce continuous ***oblique linescan imagery*** of the terrain for use by emergency services (police, fire, ambulance).

3-DAS-1

3-OC

Part II - Airborne Digital Line Scanners
(i) Inertial Measuring Units (IMUs)

(a) ***Airborne pushbroom line scanners*** cannot be operated without an **DGPS/IMU** unit giving position & attitude values for each image line.

(b) ***Airborne digital frame cameras*** can be operated without these **DGPS/IMU** units – although many are now operated in conjunction with them.

Uncorrected & Corrected Pushbroom Line Scanner Images

Part II - Airborne Digital Line Scanners
(i) Inertial Measuring Units (IMUs)

IMUs

(i) ***MEMS (Micro Electro-Mechanical Systems) Gyros*** that utilize tiny quartz tuning forks as sensors integrated on to silicon chips are coming into widespread use in the lower end systems employed on less demanding applications. ***Cost - $30,000***

(ii) ***Fibre-Optic Gyros (FOG)*** are somewhat less expensive and give a very acceptable performance that satisfies many applications

(iii) ***Ring Laser Gyros (RLG)*** are the most accurate type, but they are the most expensive to produce – which limits their use to high-end imaging systems and the most demanding applications. ***Cost – $200,000***

Part II - Airborne Digital Line Scanners
(i) Inertial Measuring Units (IMUs)

Progressive increase in accuracy is directly linked to increased cost. See the range of **POS/AV** systems supplied by **Applanix**

Table – POS/AV Absolute Accuracy Specifications – RMSE Values

Model No.	210	310	410	510	610
Position (m)	0.05 – 0.3	0.05 – 0.3	0.05 – 0.3	0.05 – 0.3	0.05 – 0.3
Velocity (m/s)	0.01	0.0075	0.005	0.005	0.005
Roll & Pitch (d)	0.04	0.015	0.008	0.005	0.0025
True Heading (d)	0.08	0.035	0.015	0.008	0.005

(i) The lower-end ***POS/AV 210, 310 and 410*** systems all use ***MEMS*** quartz gyros
(ii) The ***POS/AV 510*** system uses higher-performance ***FOG*** gyros
(iii) The top-end ***POS/AV 610*** uses highest-performance ***RLG*** gyros

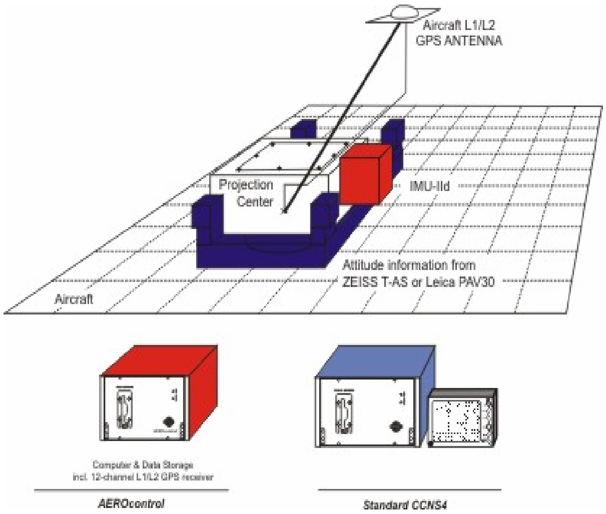
Part II - Airborne Digital Line Scanners
(ii) Differential GPS

(a) Besides the attitude (tilt and heading) values generated by the IMU, differential GPS values are also required to carry out the corrections to the continuous linescan imagery

(b) These values can be provided either from ground stations or from one of the commercial differential GPS services – such as Fugro OmniSTAR or C & C Technologies C-NAV – which operate world-wide and send the corrections using the Inmarsat satellites **N.B.** - C-NAV has 5 Russian base stations.

Part II - Airborne Digital Line Scanners
Inertial Measuring Units (IMUs) + Differential GPS

The IMU is attached rigidly to the camera. The offset between the GPS antenna and the IMU with respect to the camera projection centre needs to be determined by a prior calibration



Part III – Airborne Radar Technologies

Part III - Airborne Radar Technologies

Synthetic Aperture Radar (SAR)

Civilian SAR systems are operated by 2 main groups:-

(i) ***Commercial Service Providers***

(a) **Intermap Technologies** operates four aircraft (2 jet; 2 turbo-prop) world-wide, each equipped with its Star X-band SAR

Main business is DEM production using interferometric SAR (IfSAR) methods – NEXTmap Britain/ Germany/ USA. Now NEXTMap Europe. 1 m ground resolution + 1m RMSE vertical accuracy

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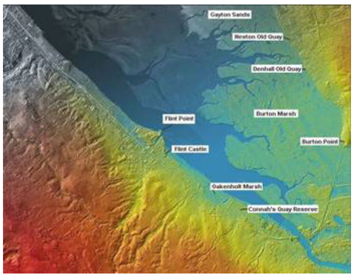
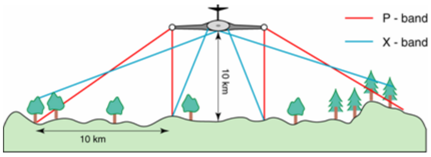
Intermap also operates a turbo-prop aircraft equipped with a P-band SAR for penetration of vegetation in thick tropical forest



Part III - Airborne Radar Technologies
Synthetic Aperture Radar (SAR)

(b) **EarthData Corporation (now Fugro)**
This company operates a single jet aircraft equipped with the GeoSAR system using two X-band and two P-band SARs.
Again the main emphasis is on DEM production – mainly in North & South America.



(ii) ***Govt. Research Agencies***
One-off SAR systems are also operated by NASA (AirSAR); DLR (E-SAR); TNO (MIniSAR); Danish Center for Remote Sensing (EMISAR); etc.

Part IV - Airborne Laser Scanners

1. *Airborne Topographic Laser Scanners*

(i) Commercial System Suppliers – Optech: Leica Geosystems; Riegl [-> IGI; TopoSys; iMAR]

(ii) Custom-Built Systems – built in-house and operated by service providers – TopEye; Fugro (FLI-MAP); TopoSys (Falcon); Terrapoint

(iii) Research Systems – NASA (ATM; RASCAL; SLICER: LVIS)

2. *Airborne Bathymetric Laser Scanners*

(i) Commercial System Suppliers – Optech; Saab (now AHAB); Tenix

(ii) Research Systems - NASA (AOL; EAARL)

Part IV - Airborne Laser Scanners

System Components

(a) **Laser rangefinder** + optics + receiver + time counter

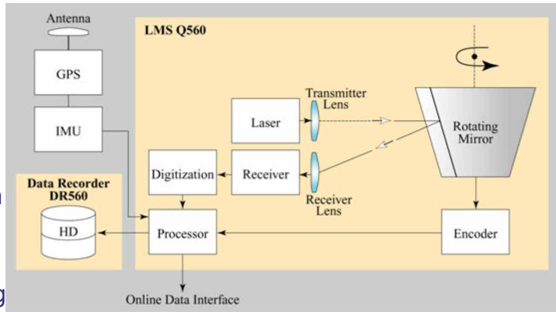
(b) **Optical Scan Mechanism** – rotating or oscillating mirror or polygon

(c) **Electronics Unit** – controls rangefinder & scan mechanism

(d) **Position & Orientation System** – GPS/IMU for position and attitude

(e) **Software** – to control system + data recording and storage

(f) **Imaging Device** – digital frame camera, video camera or line scanner



Part IV - Airborne Laser Scanners

(a) Topographic Scanners; (i) Commercial Suppliers

Optech

Airborne Laser Terrain Mapper (ALTM) – over 100 systems supplied!

Numerous models – 1020 (1993); 1225 (1999); 2033/3033 (2001-3); 3070/3100 (2005); Gemini (2006)

The ALTM laser scanners all use a very powerful (Class IV) **laser**; + an Applanix **POS/AV system** (GPS/IMU)

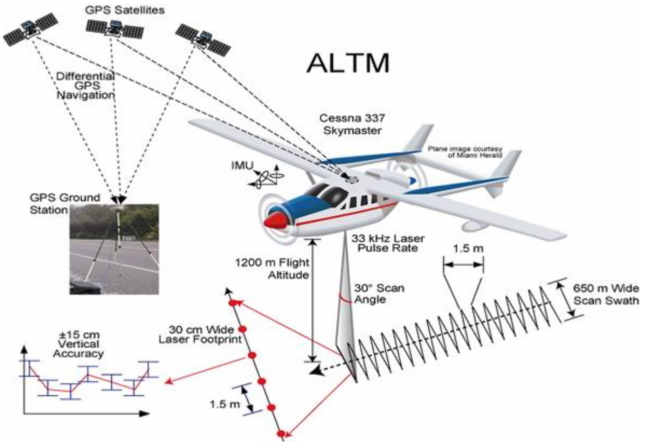
Most ALTM systems are supplied with an integrated **digital frame camera** Applanix (DSS) or Rollei (AIC)

ALTM 1020

ALTM Gemini

Part IV - Airborne Laser Scanners
(a) Topographic Scanners; (i) Commercial Suppliers

All **Optech ALTM laser scanners** use a bi-directional oscillating plane mirror to scan the ground – giving rise to a sawtooth pattern of measured points



Part IV - Airborne Laser Scanners
(a) Topographic Scanners; (i) Commercial Suppliers

Leica Geosystems

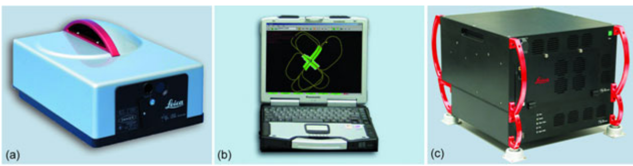
Leica bought **Azimuth Corp.** in 2001 – Aeroscan laser scanner re-badged as ALS40.

In 2003, new compact ALS50 introduced;

in 2006 improved ALS50-II model;

In 2007, new ALS50-CM Corridor Mapper

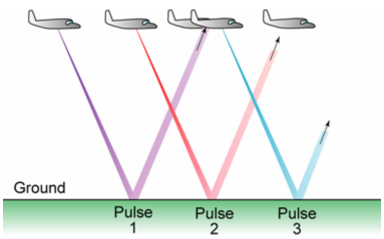
Formerly Leica used Applanix POS/AV and DSS camera; it now uses its own IPAS10 GPS/IMU and RCD105 camera



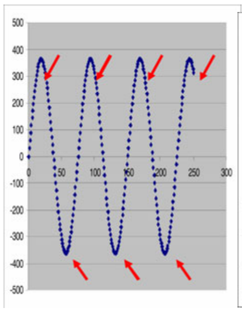
(a) ALS50 (b) Display © IPAS10

Part IV - Airborne Laser Scanners
(a) Topographic Scanners; (i) Commercial Suppliers

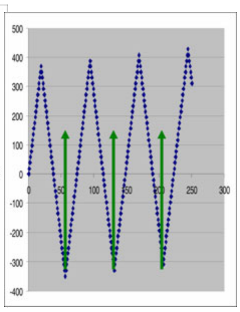
Leica ALS laser scanners also use a bi-directional scanning mirror to scan the ground - giving a sinusoidal pattern of measured points



Multiple Pulses in Air (MPIA) – Next measurement cycle begins before reflected pulse from previous cycle has been received – allows 150 kHz on ALS50-II model



Leica ALS pattern of measured ground points (sinusoidal)

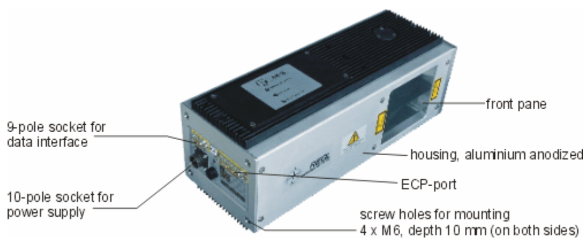


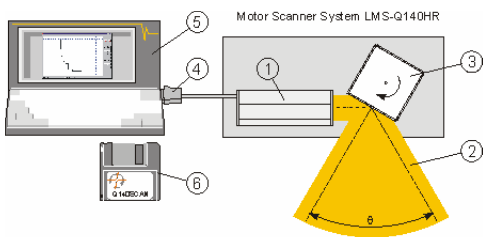
Optech ALTM pattern of measured ground points (sawtooth)

Part IV - Airborne Laser Scanners
(a) Topographic Scanners; (i) Commercial Suppliers

Riegl

Its LMS **laser scanning engines** have a continuously rotating four-faced reflecting polygon producing a **parallel pattern** of measured ground points





Part IV - Airborne Laser Scanners

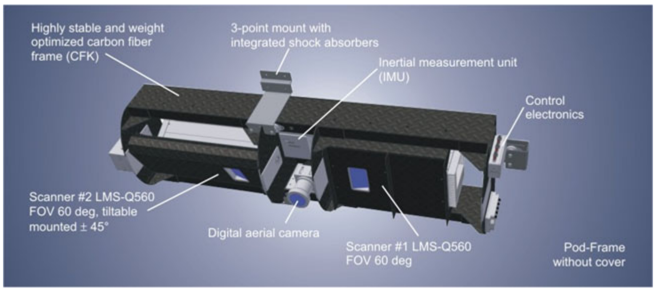
(a) Topographic Scanners; (i) Commercial Suppliers

Riegl

Mainly an OEM supplier of laser scanning engines (rangefinder + scanning mechanism), but also supplies **complete scanner systems**

Diamond DA42 MPP with scanner pod

LMS-S560 System



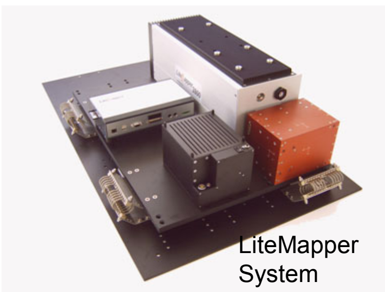
Parallel Pattern

Part IV - Airborne Laser Scanners

(a) Topographic Scanners; (i) Commercial Suppliers

Several system suppliers have built their airborne laser scanning systems on the basis of the laser scanning engines from **Riegl**. These include **IGI, TopoSys & iMAR**

TopoSys Harrier 56



LiteMapper System

IGI LiteMapper

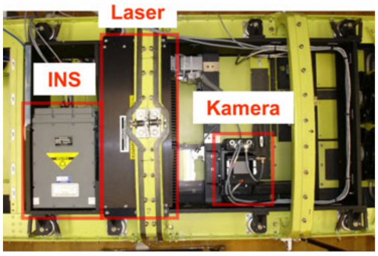
LiteMapper System mounted in a Helipod

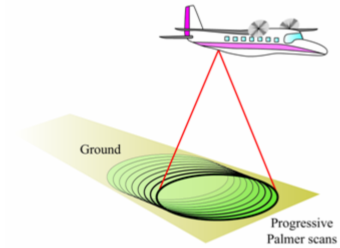
Part IV - Airborne Laser Scanners

(a) Topographic Scanners; (ii) Custom-Built Systems

TopEye

- This company (now part of Blom Group) has for many years acted as a **service provider** utilizing its own laser scanning systems built in-house for **low altitude** operation (corridor mapping)
- The earlier systems – **TopEye Mk I** – used a bi-directional oscillating mirror (like Optech ALTM and Leica ALS)
- The re-built systems – **TopEye Mk II** – use a progressive series of overlapping **elliptical (Palmer) scans** to cover the ground
- 8 systems; of which, 2 are in the U.S.A.



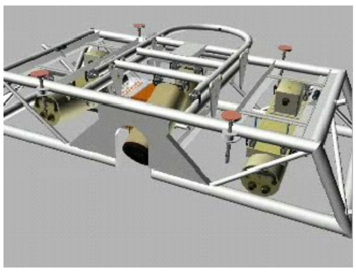


Part IV - Airborne Laser Scanners

(a) Topographic Scanners; (ii) Custom-Built Systems

Fugro

- This company also operates its **FLI-MAP** laser scanners that have been constructed in-house.
- The **FLI-MAP II** system used a continuously rotating mirror as its scan mechanism in conjunction with digital and video cameras
- The **FLI-MAP 400** system has a more powerful laser and has twin digital frame cameras and twin video cameras
- **GPS receivers** are used to measure the attitude (tilt) values
- 8 systems are in current use by John Chance (U.S.A.) & Fugro-Inpark (NL) for **low altitude** operations (corridor mapping)

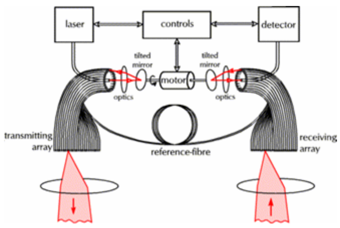


Part IV - Airborne Laser Scanners
(a) Topographic Scanners; (ii) Custom-Built Systems

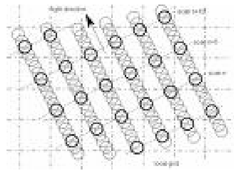
TopoSys

This company has also built its **Falcon -1; -2; and -3 systems** in-house and has used them for its operations as a service provider for a 10 year period

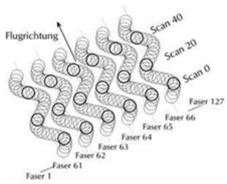
It employs a unique system comprising two linked **fibre-optic linear arrays** – the one used to transmit the laser pulses; the other to receive the reflections from the ground



Scanning Principle



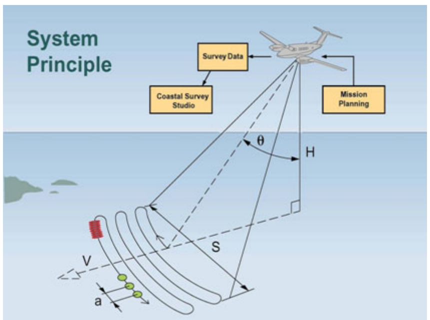
Parallel pattern of lines measured over the ground with wide spacing

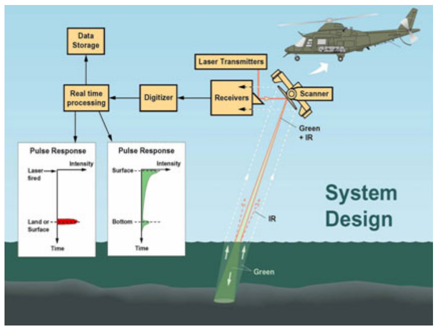


Pattern of points measured after the introduction of "swing" mirror

Part IV - Airborne Laser Scanners
(b) Airborne Bathymetric Laser Scanners

General Principles





This involves the use of two laser rangefinders emitting pulses simultaneously at different wavelengths – in the infra-red and green parts of the e-m spectrum.
The **infra-red radiation** is reflected from the water surface; whereas the pulse of **green radiation** passes into and through the water and is reflected by the seabed back towards the rangefinder. Depth is derived from the time differences

Part IV - Airborne Laser Scanners
(b) Bathymetric Scanners; (i) Commercial Suppliers

Optech

Various models – SHOALS-200 (1993); -400 (1998); -1000 (2003); -3000 (2006). Principal users are U.S. government agencies, but **Fugro** and the **Japanese Coast Guard** also operate examples

Part IV - Airborne Laser Scanners
(b) Bathymetric Scanners; (i) Commercial Suppliers

AHAB (Airborne Hydrography AB)

The company has its origins in the Saab group which built the **Hawk Eye** systems in the mid-1990s. Used by Swedish hydrographic agencies, then later by Indonesian Navy. Product rights were then sold to AHAB (ex-Saab people)

Hawk Eye II Is used by Admiralty Coastal Surveys (UK/Sweden) now owned by Blom

Part IV - Airborne Laser Scanners

(b) Bathymetric Scanners; (i) Commercial Suppliers

Tenix

- The LADS (Laser Airborne Depth Finder) was developed for the **Royal Australian Navy (RAN)** in 1993. Mounted on a Fokker F-27. Still operational – now being upgraded.!
- LADS-II is operated commercially world-wide by the **Tenix LADS Corporation**. Mounted on Dash-8.