Rio Pipeline 2005 Conference & Exposition

High Resolution Color Imagery For Ortho Maps and Remote Sensing

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Contents

- Introduction
- Antecedents
- Orthogonal projection and the line sensor
- Geometric resolution and the line sensor
- Image fusion techniques
- Map scale and the line sensor
- Height accuracy of the line sensor
- Geometric accuracy of the line sensor
- Digital surface models and the line sensor
- Radiometric resolution of the line sensor
- Remote sensing and the line sensor as BRDF research tool
- Conclusions

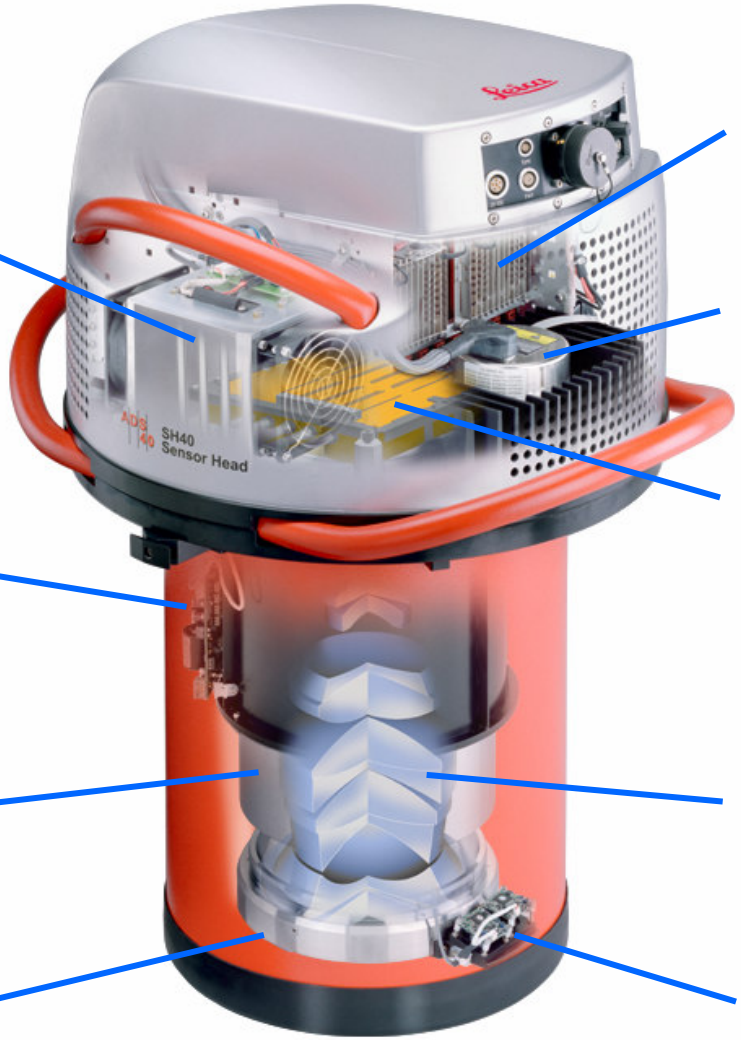
Introduction: The ADS40 Sensor Head

- 3 panchromatic CCD lines each 2 x 12,000 pixels, staggered by 3.25 μm
- 4 multispectral CCD lines, each 12,000 pixels
- Pixel size: 6.5 μm x 6.5 μm
- Field of view (FoV) or swath angle: 64°
- Focal length: 62.77 mm
- Stereo angles: 14°, 28°, 42°

Antecedents: The HRSC-A Prototype

HRSC-A Line sensor Produced by DLR for the Mars96 mission later adapted for airborne applications for "proof of concept" testing.

The final Result: Digital Sensor Head SH40



Temperature and humidity stabilization

Environmental control

Temperature and pressure stabilized lens

Glass window

Electronics

IMU

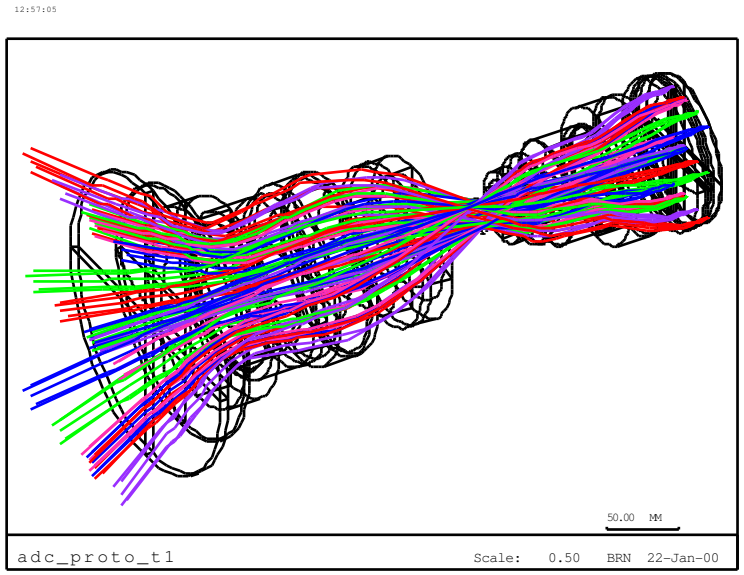
Focal plane W. CCDs lines, Interference Filters and Trichroid

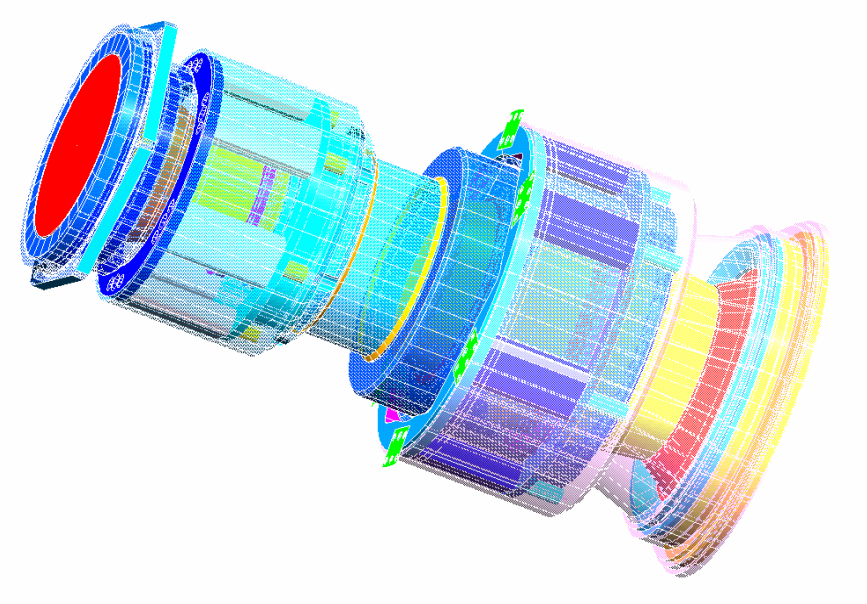
Telecentric lens w. 130 lpm resolution

Video camera

Digital Optics with Telecentric Design

- F = 62.7mm, F4
- 64° FoV (swath angle)
- Spectral range 420-900 nm
- Resolución ~ 130 lp/mm
- <u>Telecentric design</u>





- Geometric precision 1 μm
- Temperature & pressure Stabilized
  High precision range from +10°C to +30°C
- Radial distortion <= 3%

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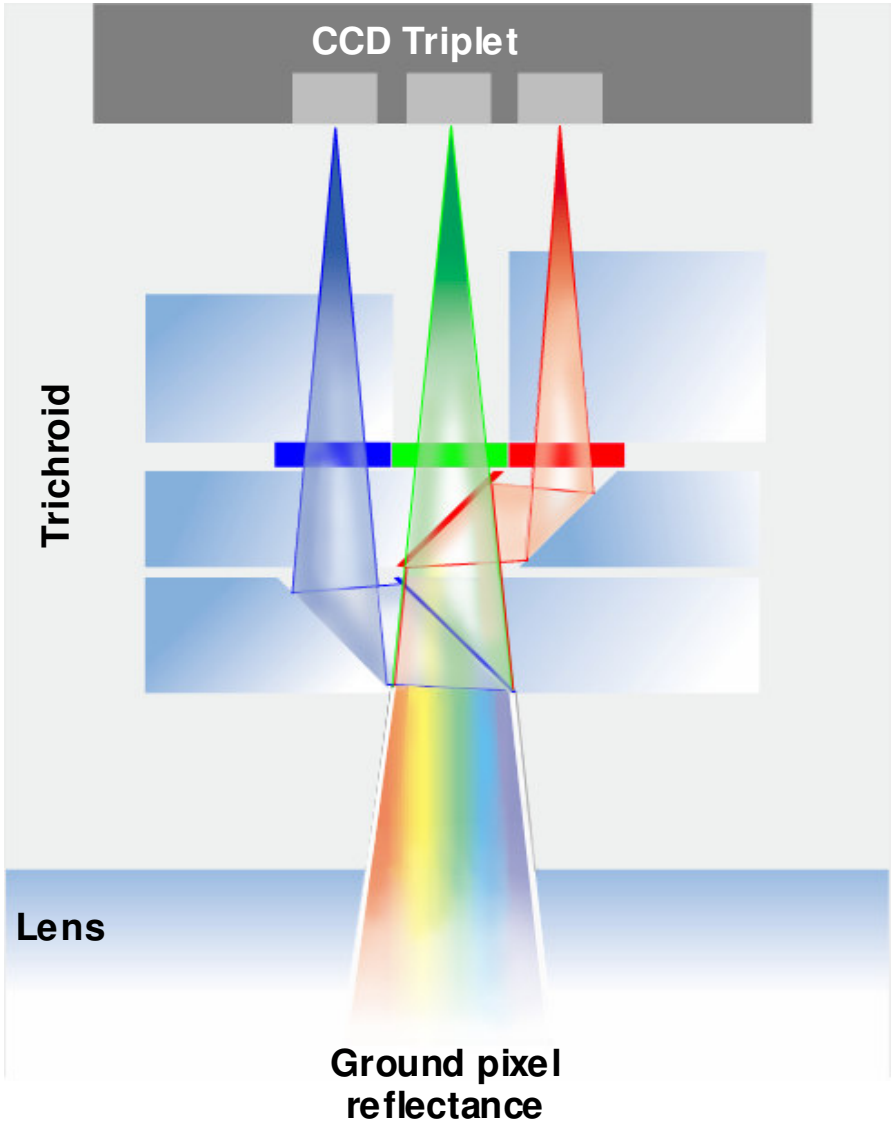
Trichroid developed by Leica for the ADS40

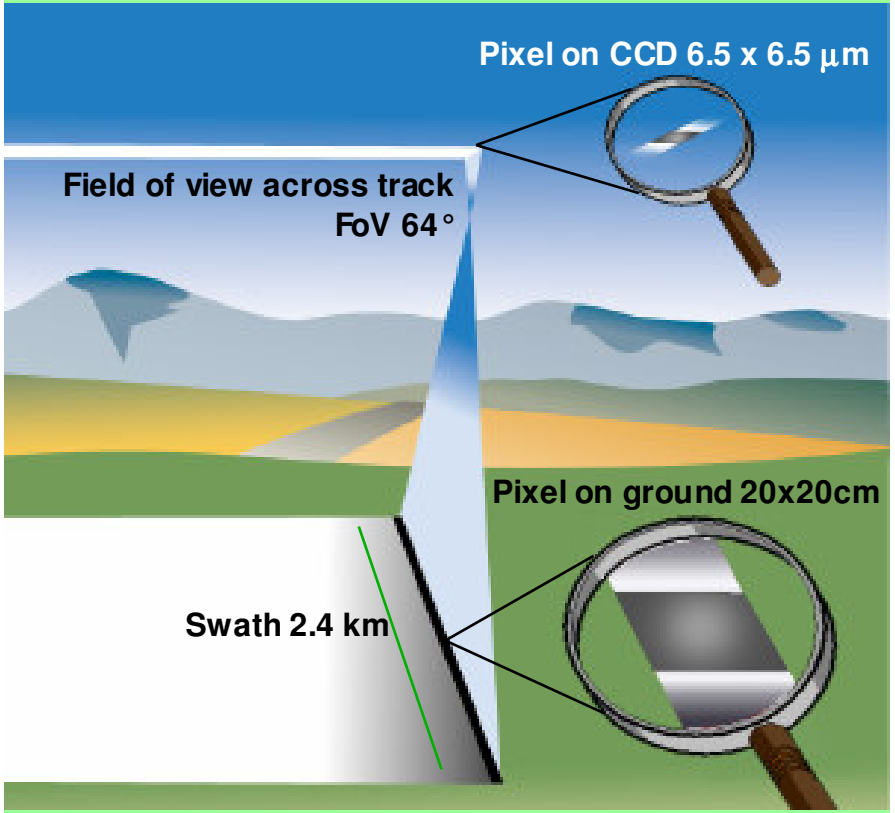


- **Optical RGB pixel co- registration device**
- **Cascaded dichroitic beam splitters**
- **Energy conservation due to spectral light splitting**
- **Metal interference filters**
- **Located between optics and CCDs**
- **Narrow band filters**

Orthogonal Projection and the line sensor

Airborne digital sensor ADS40

Example



Ground sample distance, GSD 20 cm

Analog aerial camera or digital FRAME Sensor

Example

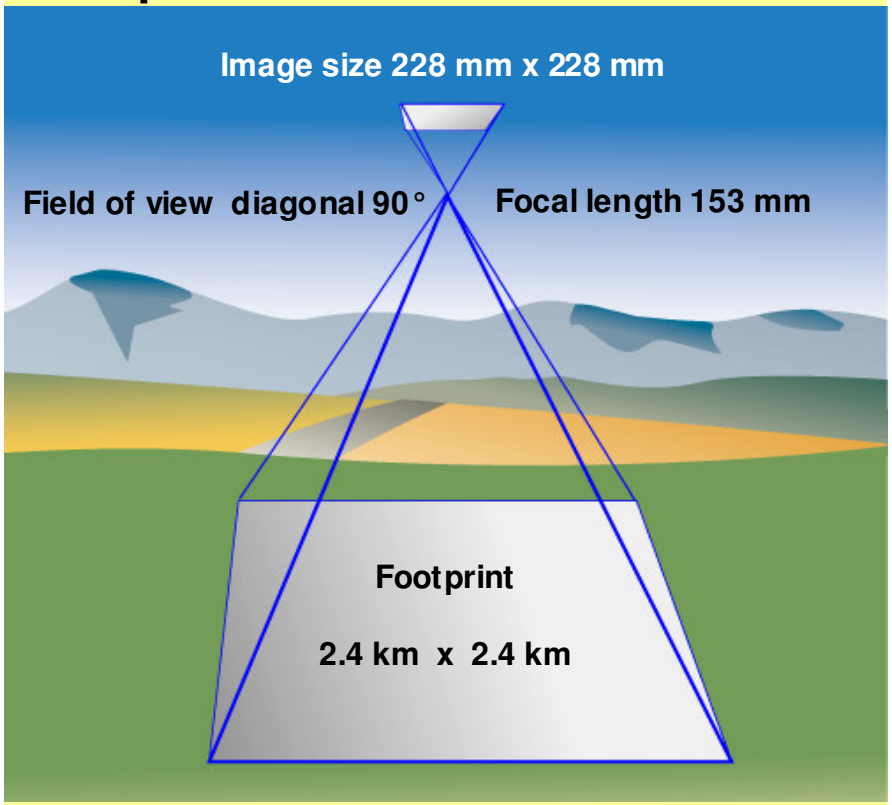
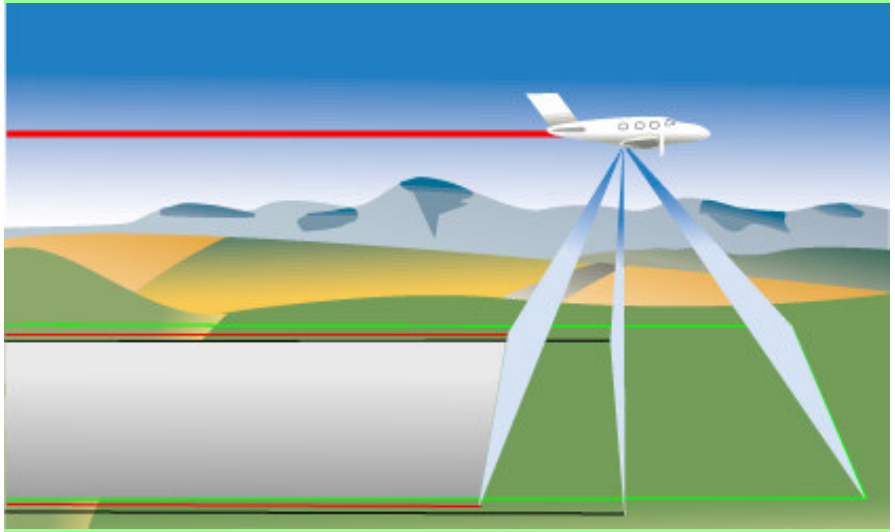


Photo scale 1 : 10,500

Image overlap

Airborne digital sensor ADS40

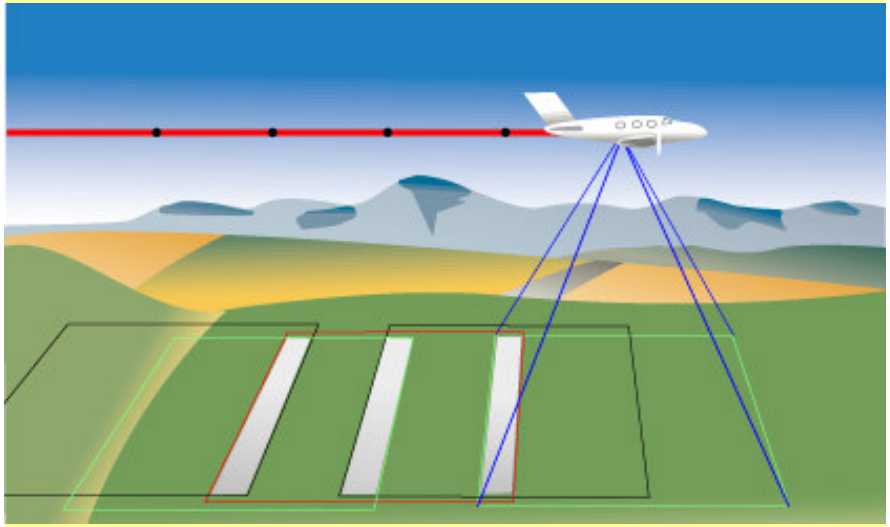
All objects recorded 3 times



100% overlapping scenes

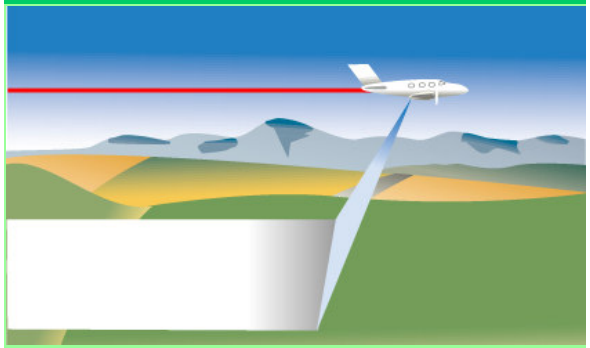
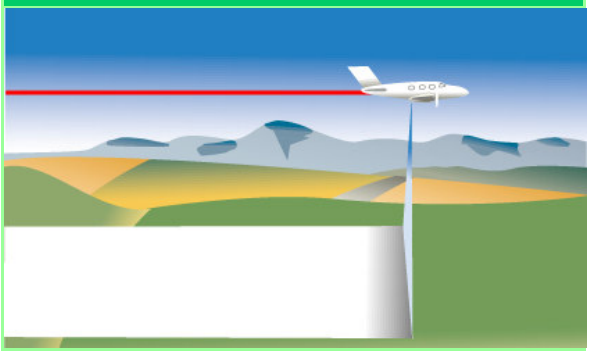
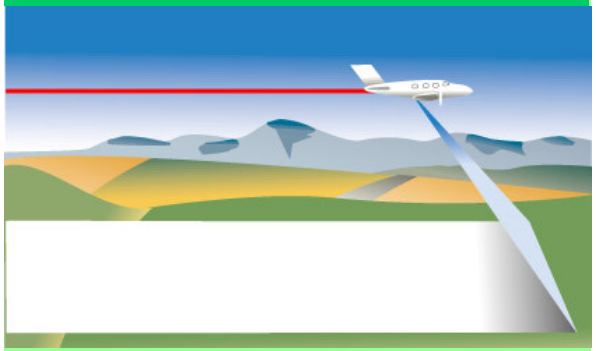
Analog aerial camera or digital FRAME sensor

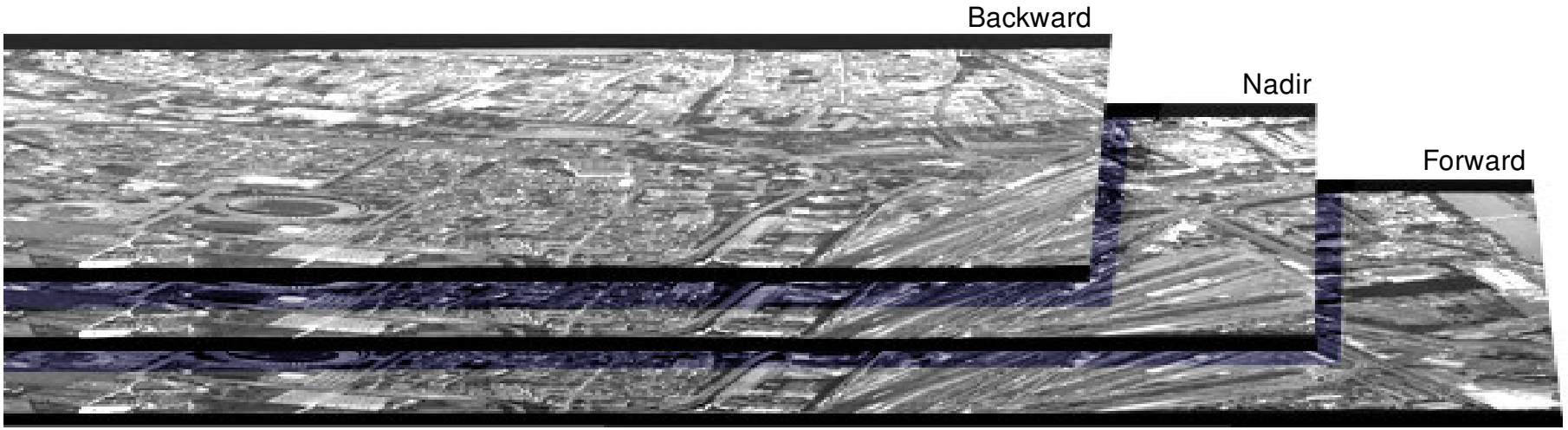
Not all objects recorded 3 times



Flying with 60% overlap only 50% of all objects are on 3 photographs

Three-line pushbroom scanner

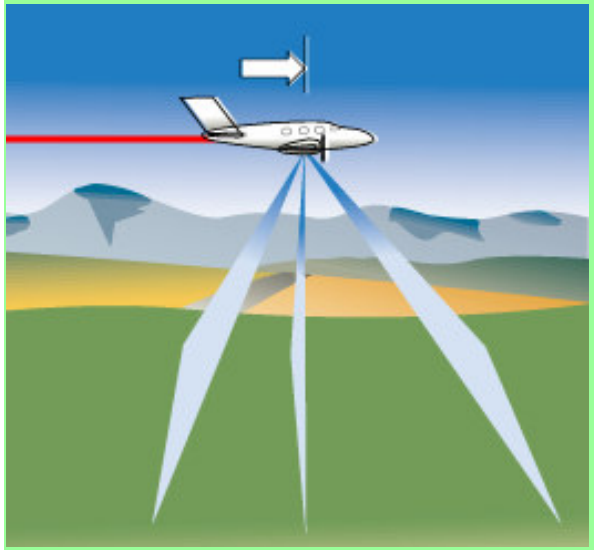
Backward scene	Nadir scene	Forward scene
		
composed of backward view lines	composed of nadir view lines	composed of forward view lines



Forward motion compensation

Pushbroom line scanner ADS40

Integration time of CCD line is always less than time needed to fly GSD



Typical example

GS 100 kts

Swath 2.4 km
GSD ~20 cm

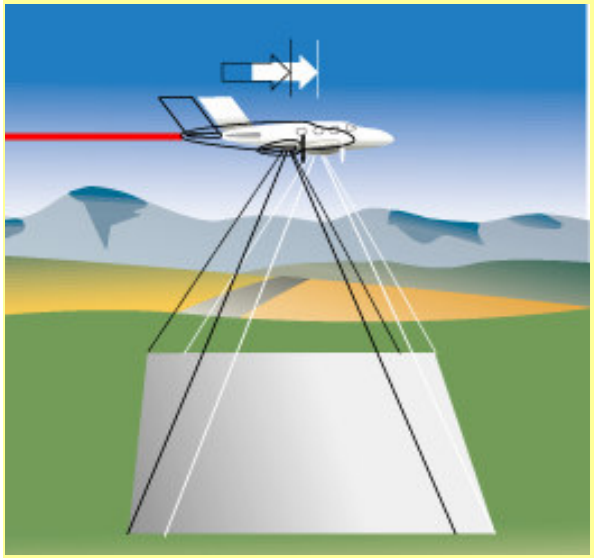
Integration time
1.2 ms

Image motion
~ 2 µm

Forward motion of aircraft during integration (exposure) can be ignored

Frame aerial camera, film based or digital

Long exposure time for film
Long integration time of CCD array



Typical example

GS 100 kts

Swath 2.4 km
Image Scale
~1:10,500

Exposure time
1/200 s

Image motion
~24 µm

Forward motion of aircraft during exposure or integration should be compensated.

Comparison of direct RGB resolution

Reference	Leica ADS40	Digital FRAME Camera
Panchromatic 12,000 pixels	Multi-spectral 12,000 pixels	Multi-spectral 3,000 pixels
		
15 cm GSD	15 cm GSD Same resolution as panchromatic	70 cm GSD From 9 to 22 x worse than panchromatic

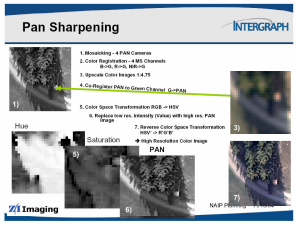
Image Fusion Techniques: Pan Sharpening

Pan sharpening of frame sensor images

Original color image
22 times lower resolution
than mosaic of pan cameras

Mosaic of 4 pan cameras

Pan sharpened color image



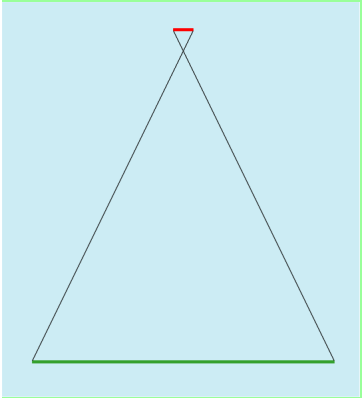
Pan sharpened color images as provided by the current digital frame sensors where not accepted in 2003 and 2004 for the NAIP projects of USDA in USA.

Advantages of ADS40 high resolution color

Leica ADS40	Frame Sensor
	
High resolution spectral CCD - no color distortion	**Pan-sharpened based on spectral data with 22x lower area resolution**
Outstanding variety of rich colors	**Bland colors**
Vegetation type can be identified	**Hard to identify vegetation type**

Irrelevance of photo scale for direct digital images

ADS40 6.5 µm CCD



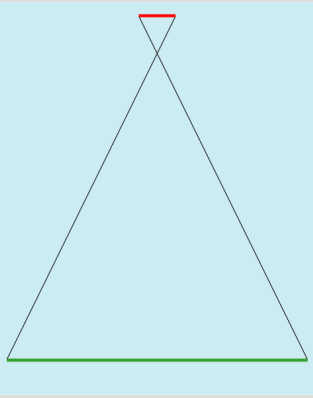
Sensor data

CCD: 12,000 pixels @ 6.5 µm
Lens: f = 63 mm, FOV 64°

Flight data for 10cm GSD

Flying height 965 m
'Photo' Scale 1 : 15,384
Swath 1,200 m

Sensor with 12 µm CCD



Sensor data

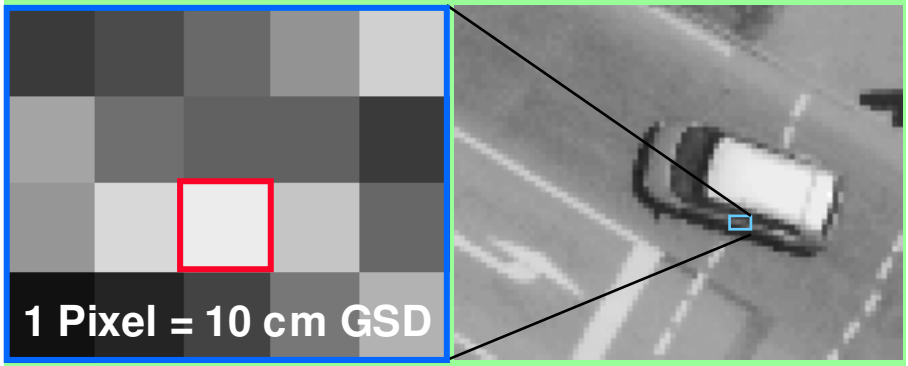
CCD: 12,000 pixels @ 12 µm
Lens: f = 120 mm, FOV 62°

Flight data for 10cm GSD

Flying height 1,000 m
'Photo' Scale 1 : 8,333
Swath 1,200 m

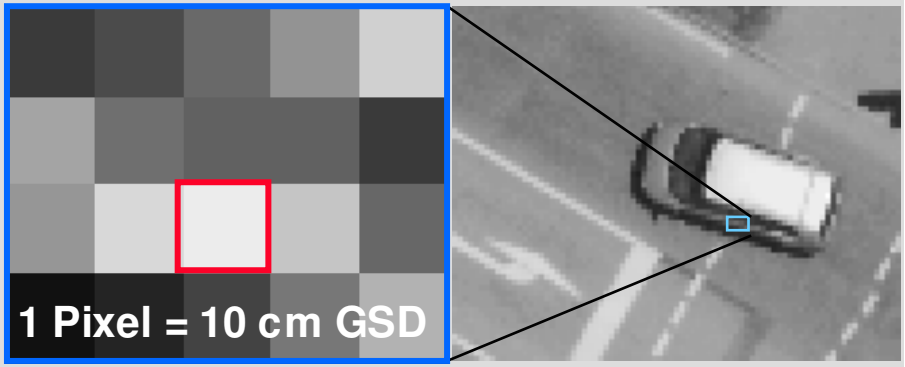
Equal GSD at different image scales - even when the CCD pixel size is different

Digital image 12,000 pixels across track



Swath on ground 1200 m

Digital image 12,000 pixels across track



Swath on ground 1200 m

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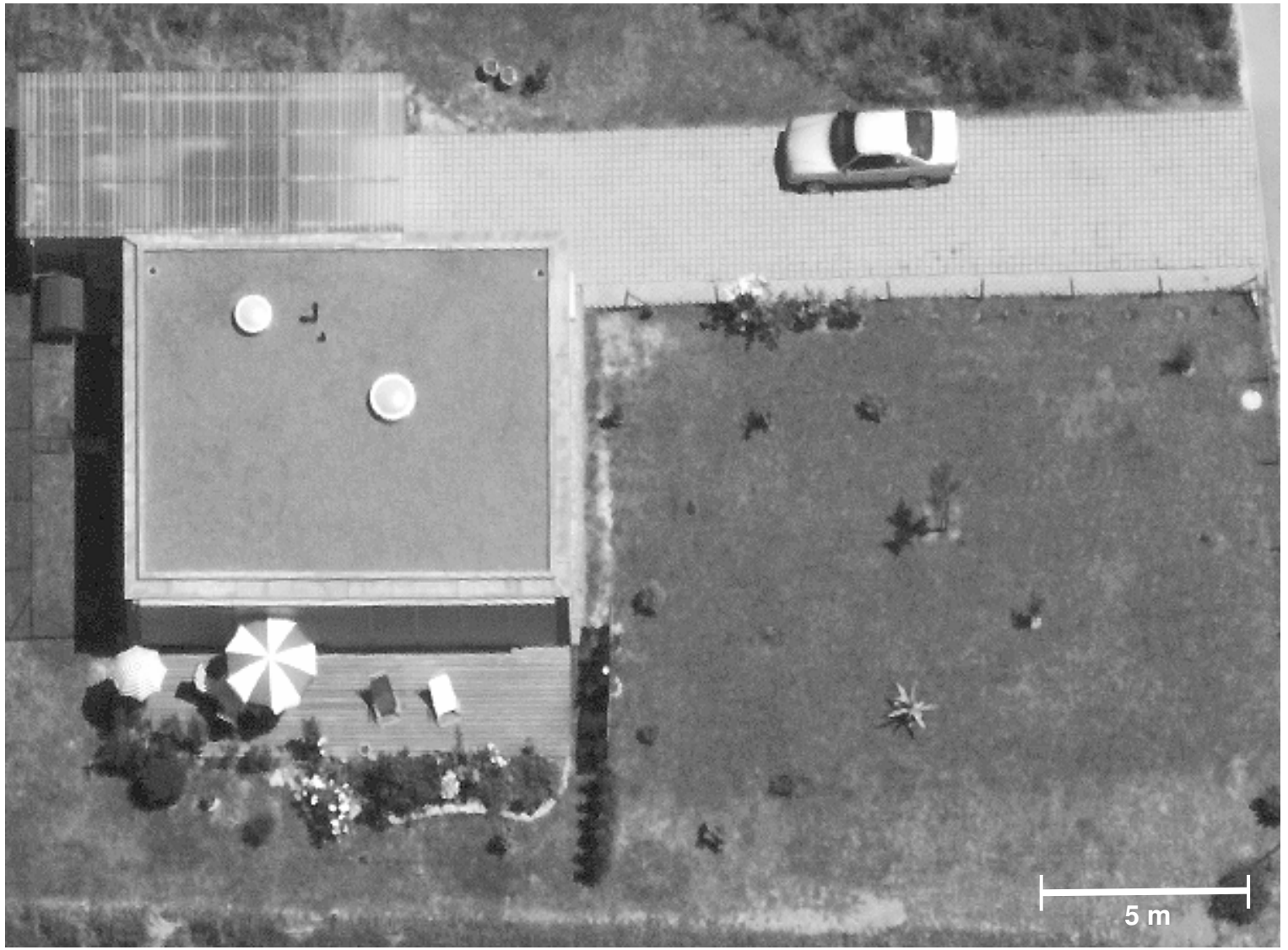
Ground Sample distance and Map Scale

Average GSD with ADS40	Map Scale	Map standard		Comparable film photographs	
		x-y accuracy RMSE	contour interval	photo scale	pixel size on ground of scanned film
5 - 10 cm	1 : 500	0.125 m	0.25 m	1 : 3,000 to 1 : 5,500	2.5 - 5 cm
10 - 15 cm	1 : 1,000	0.25 m	0.5 m	1 : 5,000 to 1 : 8,000	5 - 7.5 cm
15 - 20 cm	1 : 1,500	0.40 m	0.75 m	1 : 6,500 to 1 :10,000	7.5 - 10 cm
20 - 30 cm	1 : 2,000	0.50 m	1m	1 : 8,000 to 1 : 11,000	10 - 15 cm
25 - 35 cm	1 : 2,500	0.60 m	1.25 m	1 : 8,500 to 1 : 13,000	12.5 - 17.5 cm
30 - 50 cm	1 : 5,000	1.25 m	2.5 m	1 : 12,000 to 1 : 18,000	15 - 25 cm
40 - 60 cm	1 : 10,000	2.50 m	5m	1 : 17,000 to 1 : 27,000	20 - 30 cm
50 - 70 cm	1 : 20,000	5.00 m	10 m	1 : 25,000 to 1 : 35,000	25 - 35cm
50 - 80 cm	1 : 25,000	6.25 m	12.5 m	1: 28,000 to 1 : 42,000	25 - 40 cm
50 - 100 cm	1 : 50,000	12.5 m	20 m	1 : 40,000 to 1 : 60,000	25 - 50 cm
50 - 100 cm	1 : 100,000	25 m	50 m	1 : 60,000 to 1 : 90,000	25 - 50 cm

ADS40 image - 5 cm GSD - Vaihingen, Germany

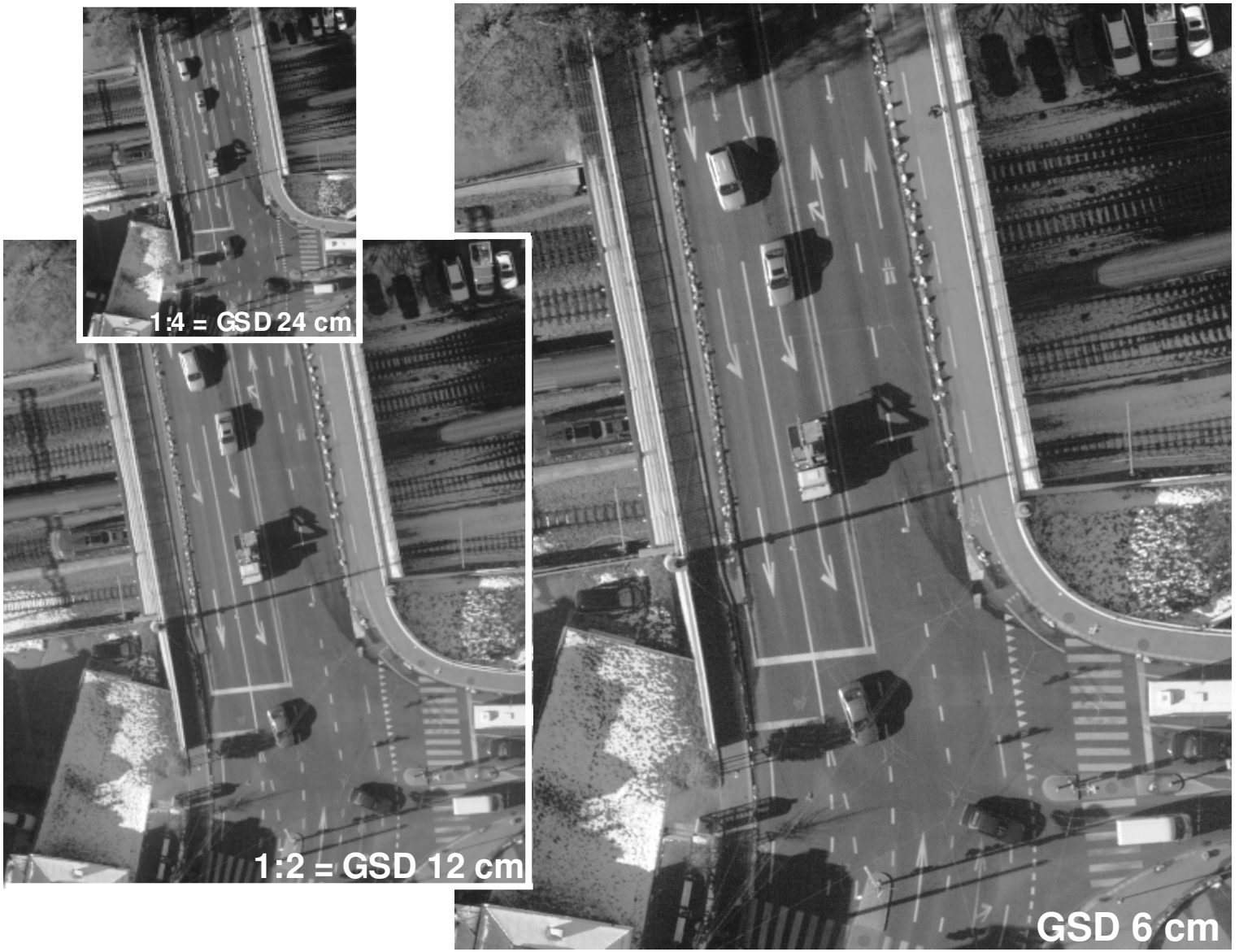


Ground sample distance:
GSD ≈ 5 cm
GSD ≈ 1/5 ft

Flying height:
480 m
1,580 ft

26 June 2004

ADS40 image – St. Gallen, Switzerland



Ground sample distance:
GSD ≈ 6 cm
GSD ≈ 1/5 ft

Flying height:
580 m
1,900 ft

November 2003
Sun elevation 23°

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Comparison of height/base ratio of digital sensors & cameras

	Comparison of Aerial Cameras				Comparison of Area coverage, and accuracy						
Camera Type	Individual camera parameters				Normalized to pixel of 10 um & 10 cm GSD						
					(normalized photo scale 1:10,000)						
					Area coverage				Accuracy		
	Array (Pixels)	Pixel size um	Focal length mm	GSD @ 1000m cm	n.focal length mm	Area sq.km	**h/b ratio**		x,y cm	height (points) cm	height (terrain) cm
ADS40	12000 x 1	6.5	62.5	10.4	96	1.44	**1.26**		20	12.6	24.2
DMC (Pan)	13824 x 7680	12	120	10	100	1.06	**3.3**		20	33	66
UltraCam (Pan)	11500 x 7500	9	100	9	111	0.86	**3.7**		20	37	74
DIMAC	5440 x 4800	9	120	7.5	134	0.26	**4.7**		20	47	94
Aerial Photo (UAG)	15333 x 15333	15	153	9.8	103	2.35	**1.66**		20	16	32
Aerial Photo (NAT)	15333 x 15333	15	305	4.9	204	2.35	**3.32**		20	32	64

Geometric Accuracy of the ADS40

Results obtained by the University of Stutgart in 2004

	East	North	Vertical
RMS [m]	0.052	0.054	0.077
Mean [m]	0.000	-0.022	0.045
Max. [m]	0.133	0.188	0.242

- **GSD = 15 cm**
- **Flying Height 1500 m**
- **12 Ground Control Points for adjustment**
- **198 Check points for absolute accuracy test**

Digital Surface Models obtained from ADS40

DSM derived from 30 cm GSD

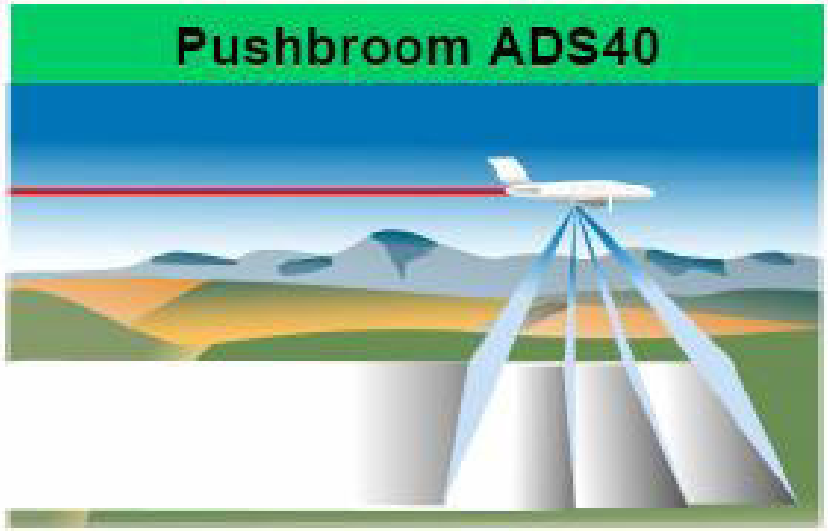
True Ortho Map based on a 30 cm GSD DSM

Radiometric resolution of the ADS40

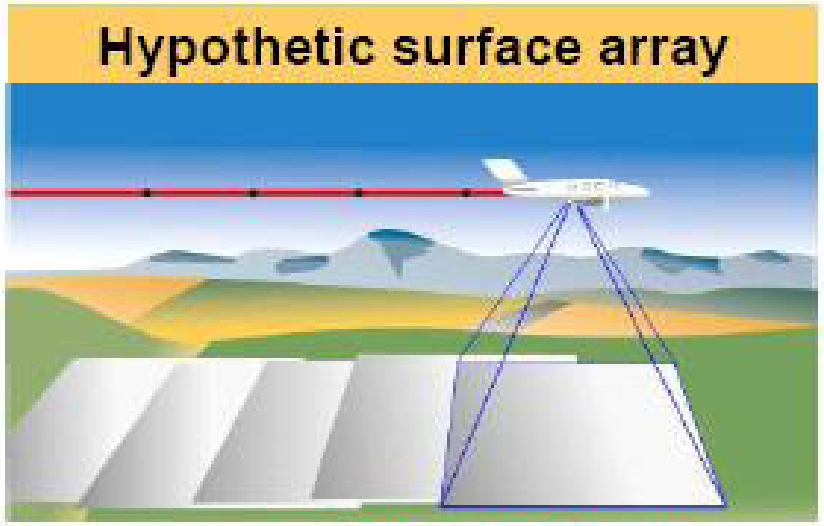
Leica ADS40	Frame Sensor
	
High resolution spectral CCD - no color distortion	Pan-sharpened based on spectral data with 22x lower resolution
Outstanding variety of rich colors	Dull colors
Tree types can be easily identified	Different tree types appear similar

Conclusions

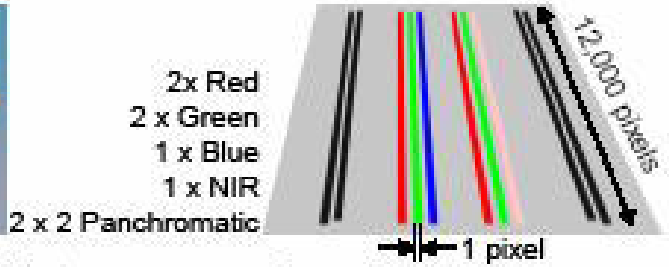
How to match the line sensor performance with frame technology?



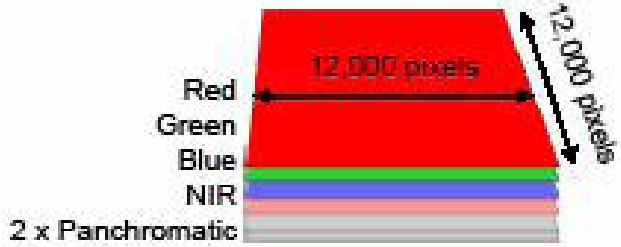
Single lens with a focal plate with 10 CCD lines.
Trichroid features co-registration of spectral bands.



Single lens with a hypothetic surface array with six transparent layers for co-registration.



- 50 MB data per second
- Pixel carpets, continuous recording
- Up to 175 GB image data per hour



- 720 MB data per multi-layer frame
- Frames at a rate of > 2 second bursts
- Up to 1,256 GB image data per hour

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Thank you!

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