Univerzita Pavla Jozefa Šafárika v Košiciach
Prírodovedecká fakulta
Ústav geografie

Diaľkový prieskum Zeme
Pasívne multispektrálne skenovanie

Doc. Mgr. Michal Gallay, PhD.
michal.gallay@upjs.sk

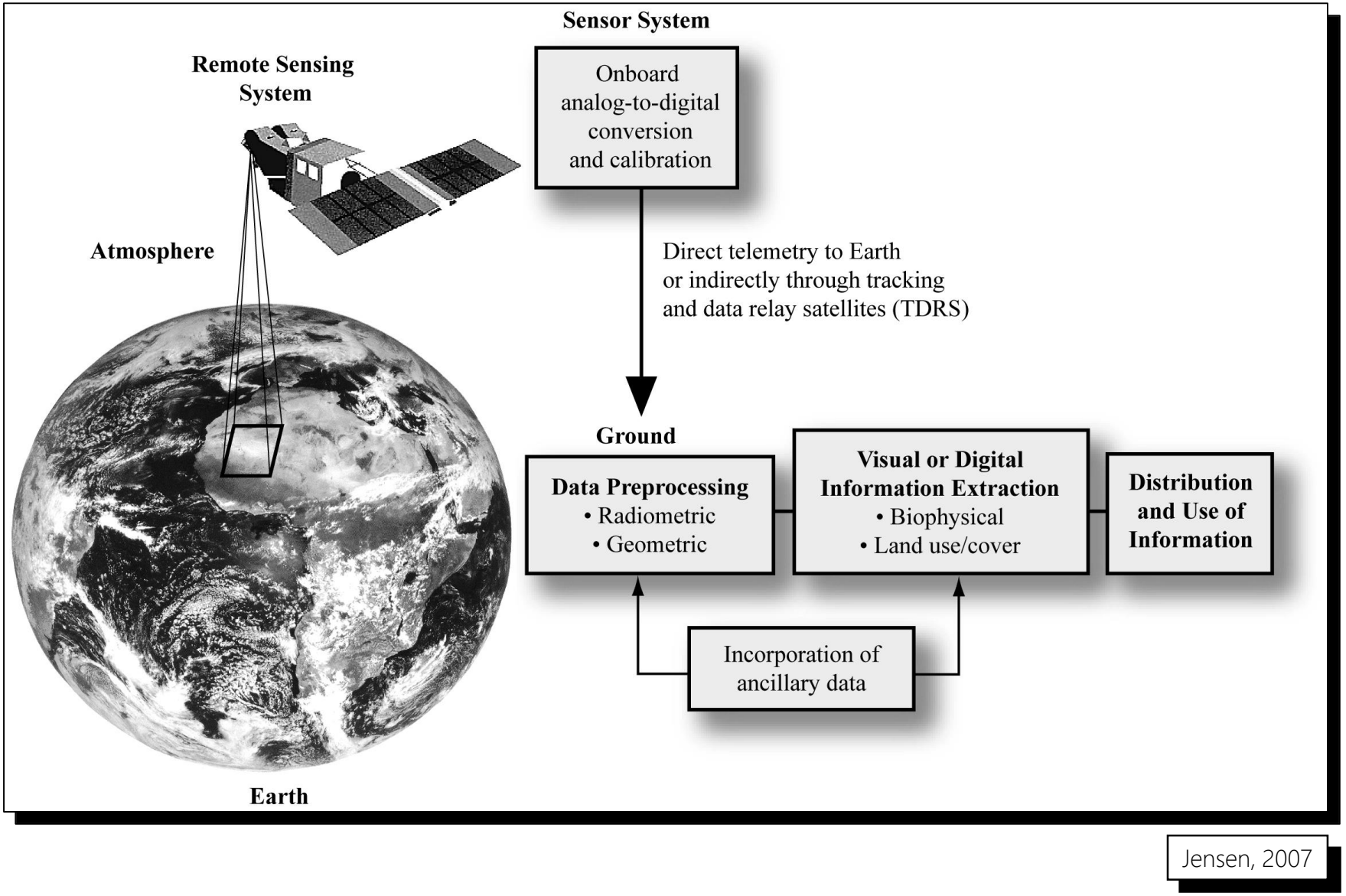
Pasívne multispektrálne skenovanie

- Pasívna metóda DPZ
- po II. sv. vojne náhrada analógovej fotografie
- problémy klasického filmu
  - obmedzené spektrálne rozlíšenie (VID + blízke IČ)
  - latentný záznam – film treba vyvolať, ustáliť, oprať
  - prenos na diaľku nemožný
- skener – digitálne rozkladové zariadenie
  - obraz vzniká po riadkoch na rozdiel analógovej fotografie
  - prenos obrazu možný na diaľku (digitálny)

Dva základné spôsoby získania digitálneho obrazu:

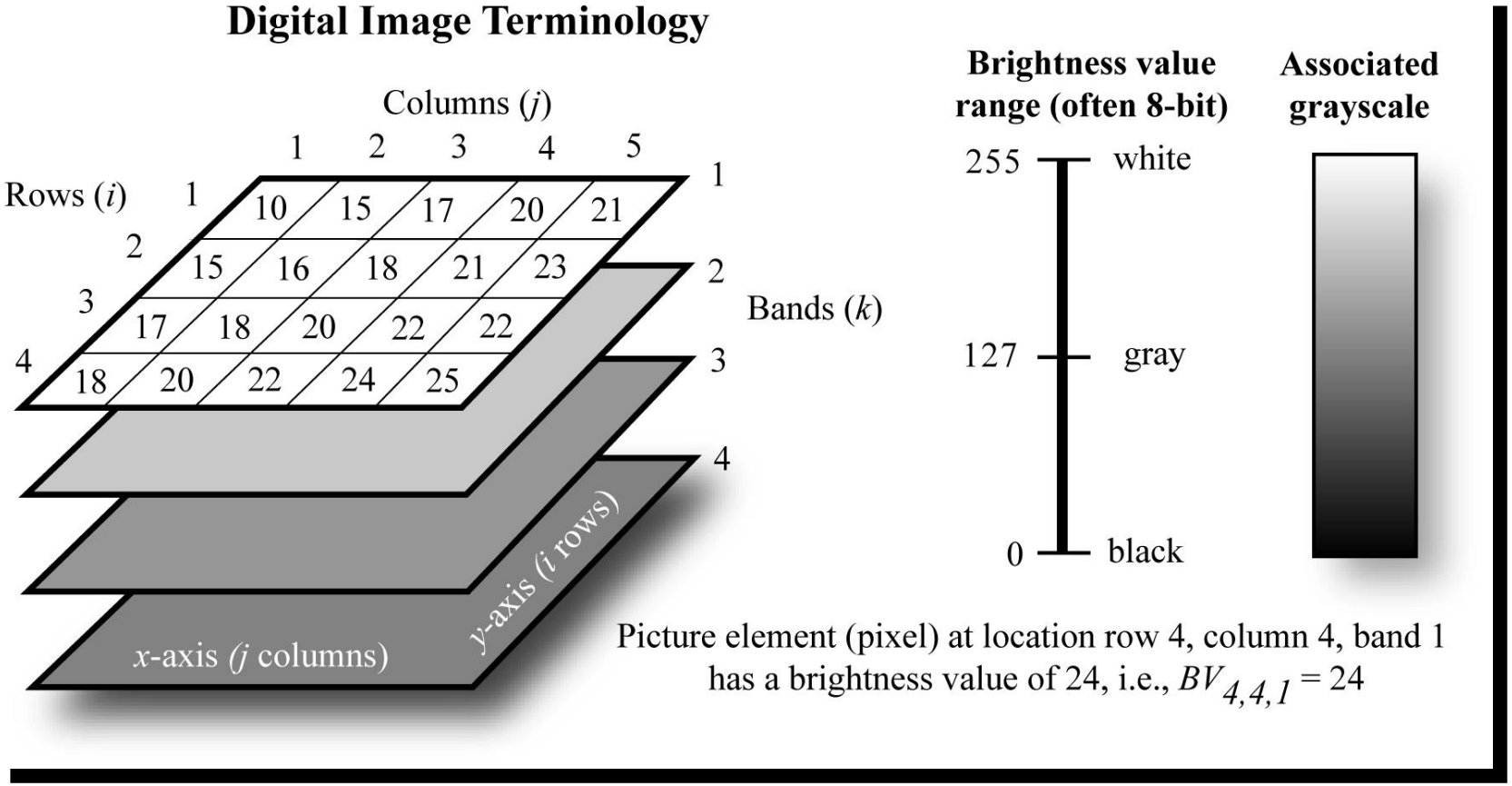
- získať obraz v analógovom formáte (fotografický film alebo papier) a potom ho konvertovať do digitálneho formátu v procese digitalizácie,
- získať obraz priamo v digitálnom formáte (napr. systém Landsat 7 Enhanced Thematic Mapper Plus (ETM+)).

Transformácia analógového záznamu DPZ do digitálneho záznamu a jej prenos na Zem do podoby užitočnej informácie



Jensen, 2007

Rastrový údajový formát záznamu DPZ
(matica hodnôt, angl. matrix, grid, raster, array)

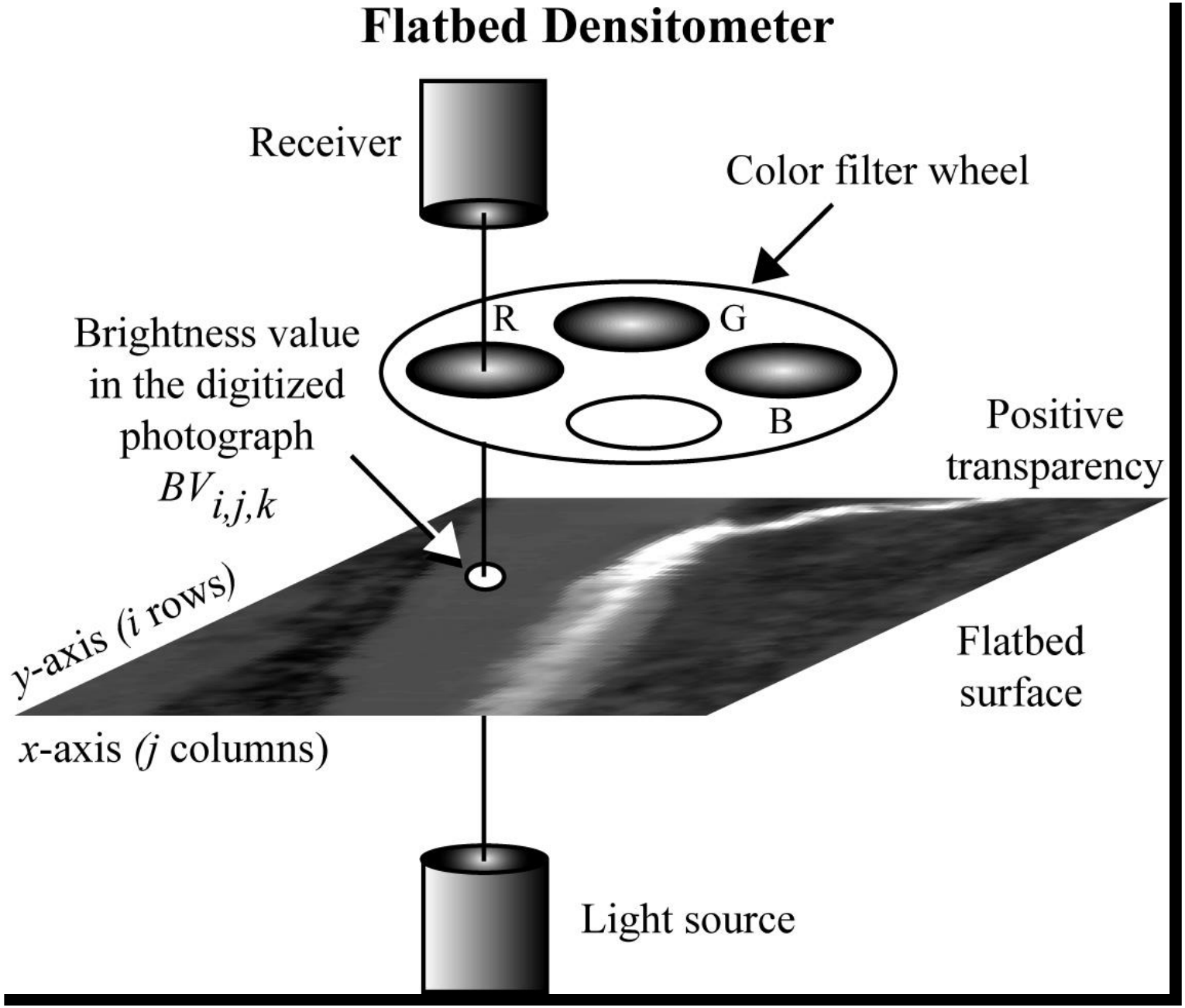


Jensen, 2007

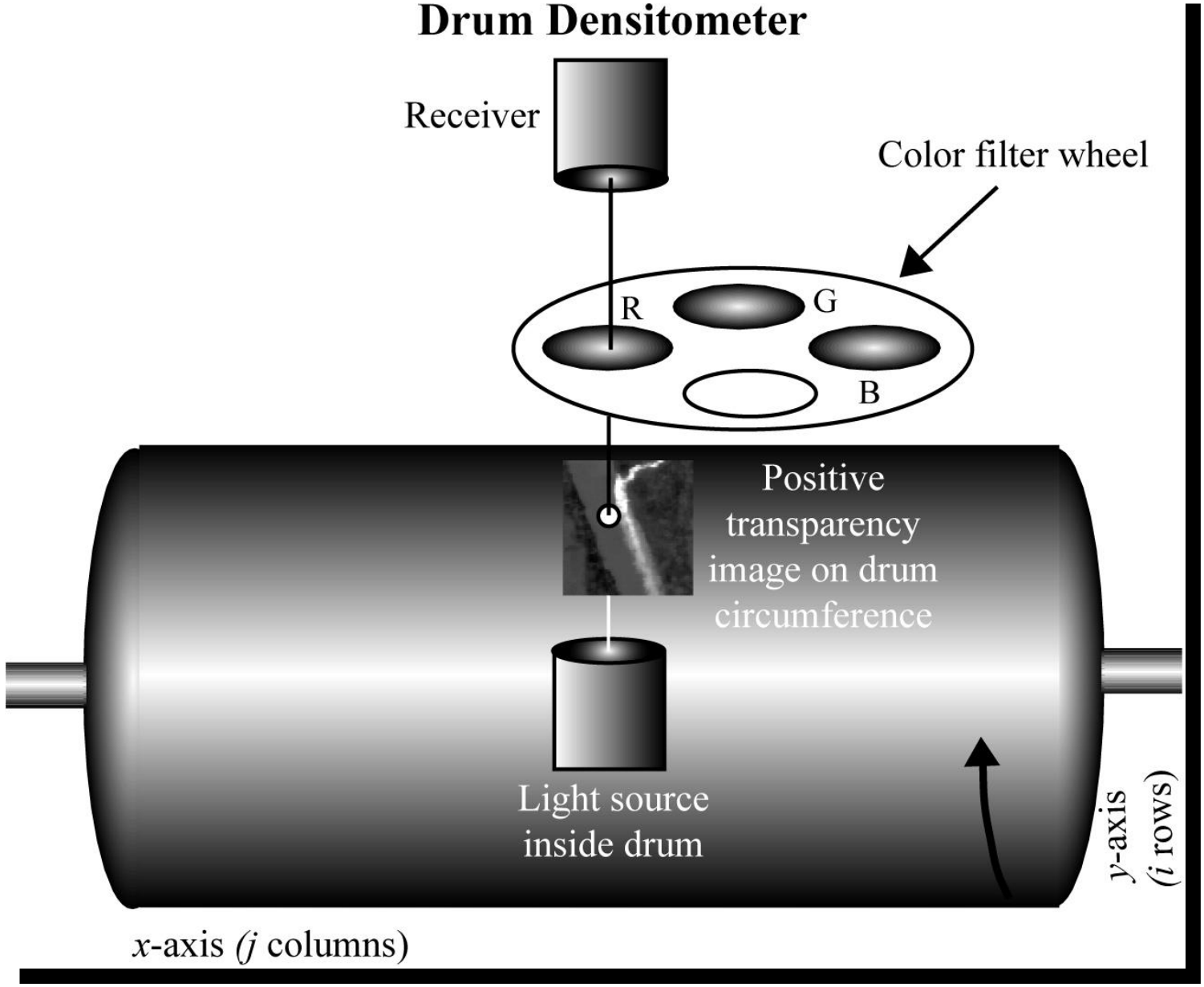
Konverzia analógového záznamu do digitálneho

- Opto-mechanický princíp
- Opto-elektronický princíp

Filmový negatív a pozitív


Flatbed Densitometer
Receiver
Color filter wheel
R
G
B
Brightness value
in the digitized
photograph
$BV_{i,j,k}$
Positive
transparency
y-axis (i rows)
Flatbed
surface
x-axis (j columns)
Light source

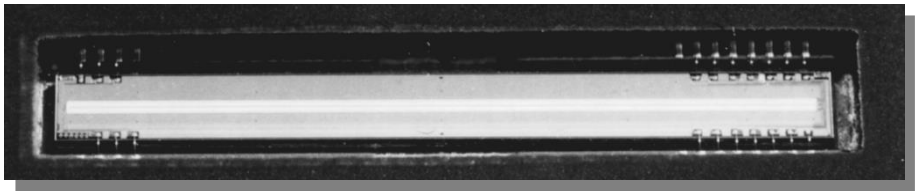
Jensen, 2007


Drum Densitometer
Receiver
Color filter wheel
R
G
B
Positive transparency image on drum circumference
Light source inside drum
y-axis (i rows)
x-axis (j columns)

Jensen, 2007

Stolový riadkový skener

Linear Array CCD

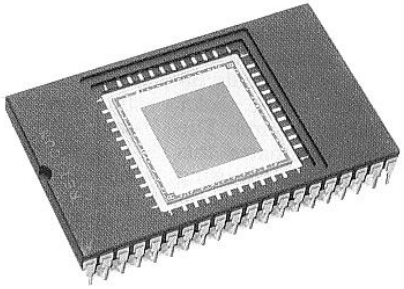


Linear Array CCD Flatbed Digitizer

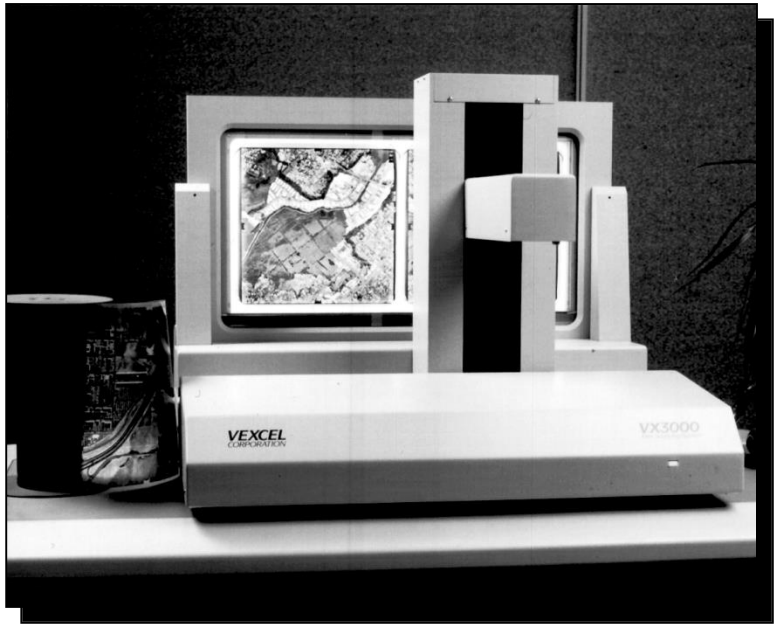
Jensen, 2007

Stolový plošný skener

Area Array CCD



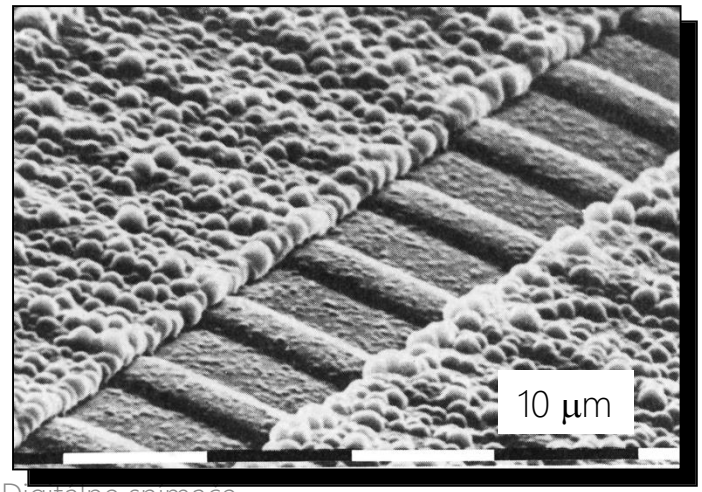
Area Array CCD Image Digitizer



Jensen, 2007

CCD

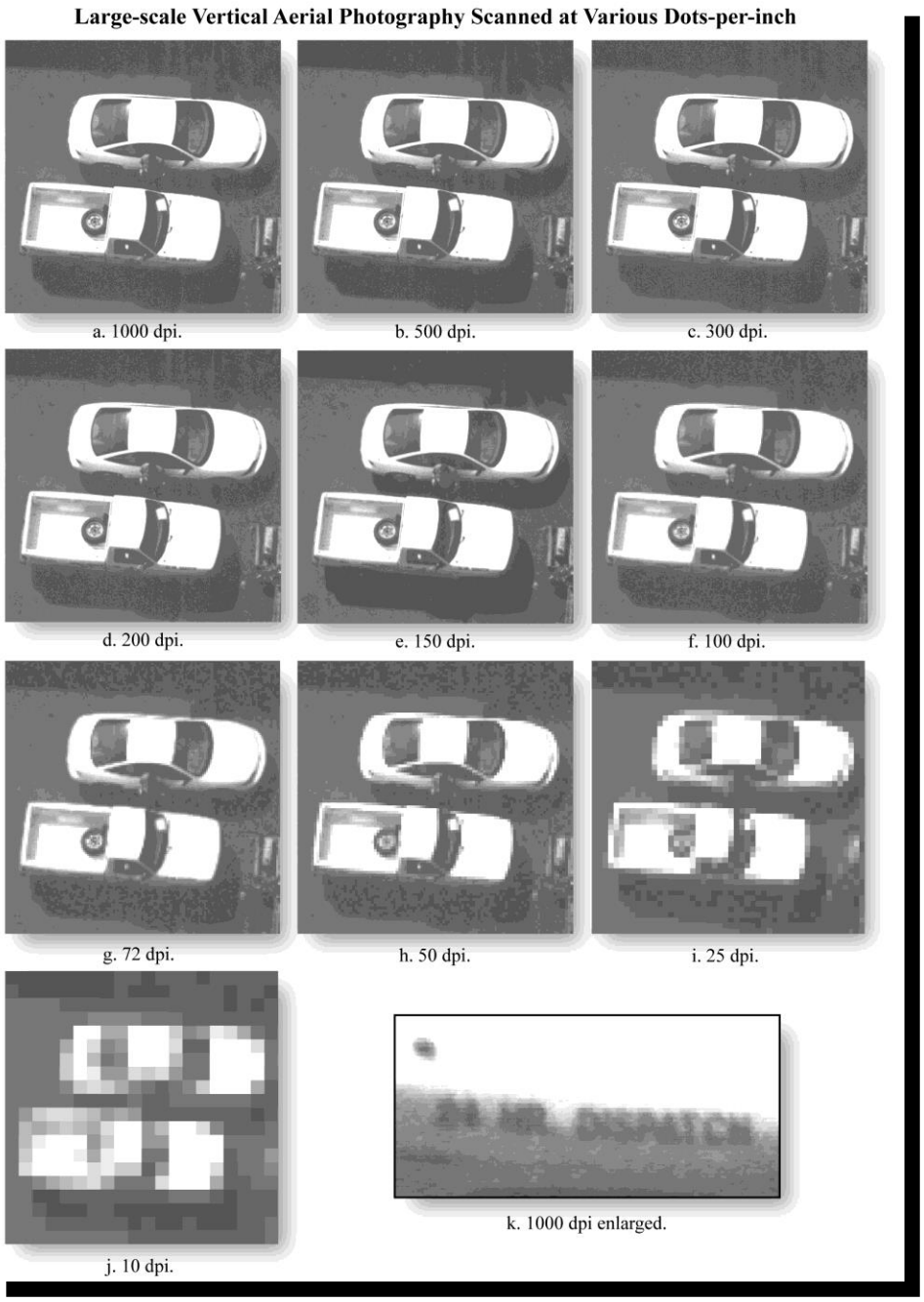
- Charge-Coupled Device" - nábojovo viazaná štruktúra
- Svetlocitlivý čip zložený z detektorov o veľkosti cca. 20 x 20 mikrometrov
- Náboj, ktorý vznikne na polovodiči po osvetlení vďaka vnútornému fotoelektrickému javu (Einstein), je postupne vysúvaný k okraju prvku (čipu), kde je elektricky zosilnený a následne spracovaný.



Courtesy of
SPOT Image, Inc.

Jensen, 2007

Digitalizovaná fotografia s rôznym rozlíšením obrazu (DPI)



Jensen, 2007

Digitizer Detector IFOV		Pixel Ground Resolution at Various Scales of Photography (m)					
Dots per inch	Micrometers	1:40,000	1:20,000	1:9,600	1:4,800	1:2,400	1:1,200
100	254.00	10.16	5.08	2.44	1.22	0.61	0.30
200	127.00	5.08	2.54	1.22	0.61	0.30	0.15
300	84.67	3.39	1.69	0.81	0.41	0.20	0.10
400	63.50	2.54	1.27	0.61	0.30	0.15	0.08
500	50.80	2.03	1.02	0.49	0.24	0.12	0.06
600	42.34	1.69	0.85	0.41	0.20	0.10	0.05
700	36.29	1.45	0.73	0.35	0.17	0.09	0.04
800	31.75	1.27	0.64	0.30	0.15	0.08	0.04
900	28.23	1.13	0.56	0.27	0.14	0.07	0.03
1000	25.40	1.02	0.51	0.24	0.12	0.06	0.03
1200	21.17	0.85	0.42	0.20	0.10	0.05	0.03
1500	16.94	0.67	0.34	0.16	0.08	0.04	0.02
2000	12.70	0.51	0.25	0.12	0.06	0.03	0.02
3000	8.47	0.33	0.17	0.08	0.04	0.02	0.01
4000	6.35	0.25	0.13	0.06	0.03	0.02	0.008

Useful Scanning Conversions

DPI = dots per inch; μm = micrometers; I = inches; M = meters

From DPI to micrometers: $\mu m = (2.54 / DPI)10{,}000$

From micrometers to DPI: $DPI = (2.54 / \mu m)10{,}000$

From inches to meters: $M = I \times 0.0254$

From meters to inches: $I = M \times 39.37$

Computation of Pixel Ground Resolution

PM = pixel size in meters; PF = pixel size in feet; S = photo scale

Using DPI: $PM = (S/DPI)/39.37$ $PF = (S/DPI)/12$

Using micrometers: $PM = (S \times \mu m)\ 0.000001$ $PF = (S \times \mu m)\ 0.00000328$

For example, if a 1:6,000 scale aerial photograph is scanned at 500 dpi, the pixel size will be (6000/500)/39.37 = 0.3048 meters per pixel, or (6000/500)/12 = 1.00 foot per pixel. If a 1:9,600 scale aerial photograph is scanned at 50.8 μm, the pixel size will be $(9{,}600 \times 50.8)(0.000001) = 0.49$ meters, or $(9{,}600 \times 50.8)(0.00000328) = 1.6$ feet per pixel.

Relationship between digitizer instantaneous-field-of-view measured in dots per inch or micrometers, and the pixel ground resolution at various scales of photography.

Jensen, 2007

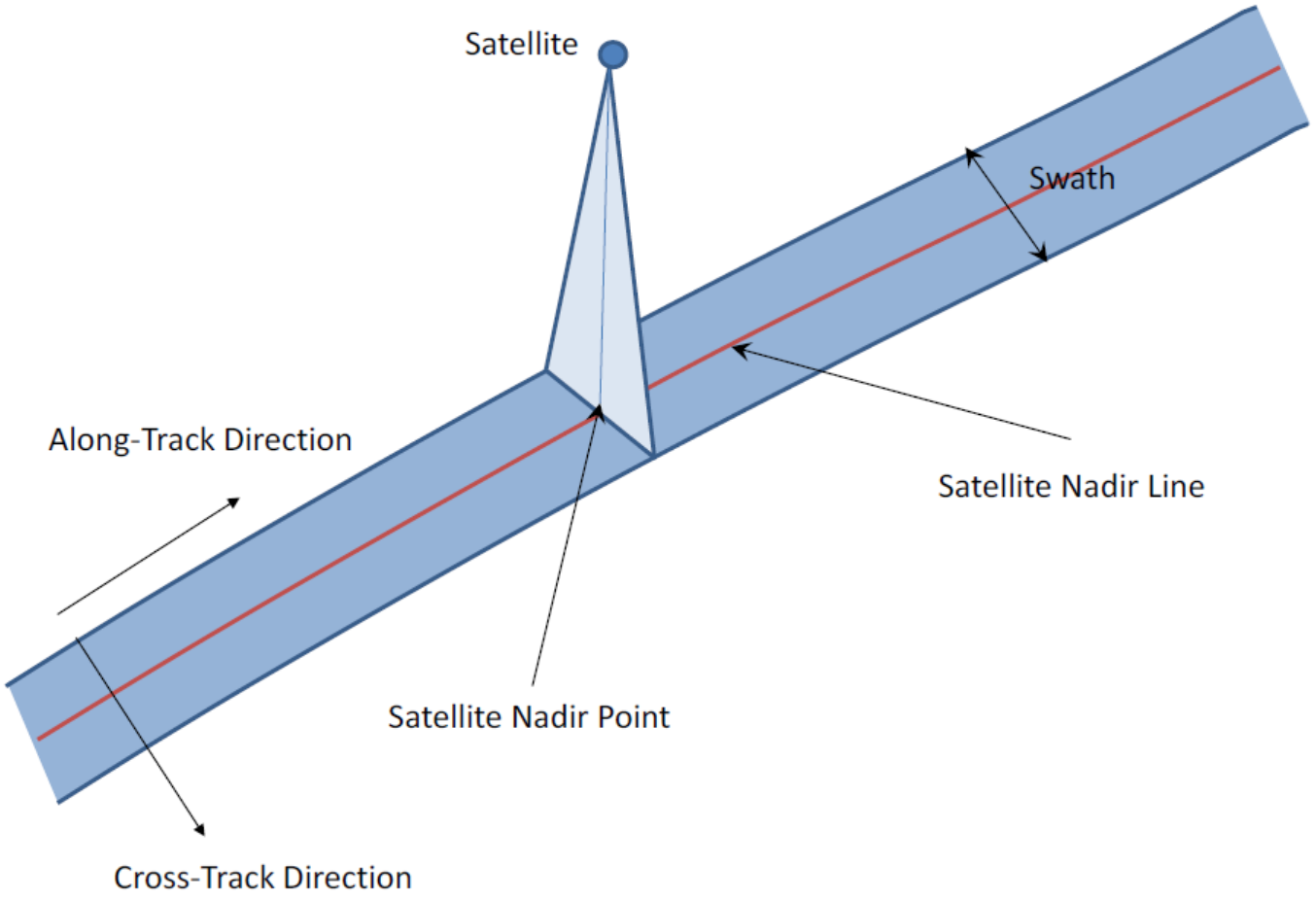
Získavanie záznamu DPZ priamo v digitálnom formáte

Multispektrálne skenovanie

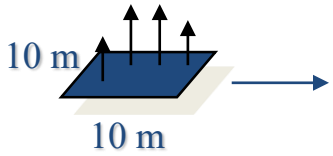
Skenery a DPZ

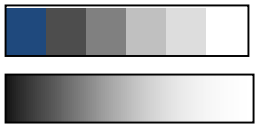
- Princíp funkcie skenera je v **snímaní zemského povrchu v pruhoch kolmých na smer letu nosiča skenera.**
- Nosičmi sú napr. **družice** Landsat, SPOT.
- Skenery
  - **opticko – mechanické** - pruh snímajú po častiach (jednotlivých pixloch)
  - **opticko – elektronické** – pruh snímajú naraz (celý riadok alebo plochu pixlov naraz)
- Na snímanie žiarenia snímače využívajú zrkadlovú optiku.
- **Monospektrálne** alebo **multispektrálne snímanie**

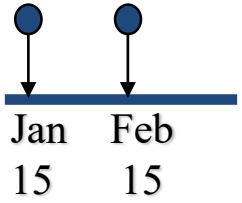
Všeobecná geometria snímania a kľúčové slová



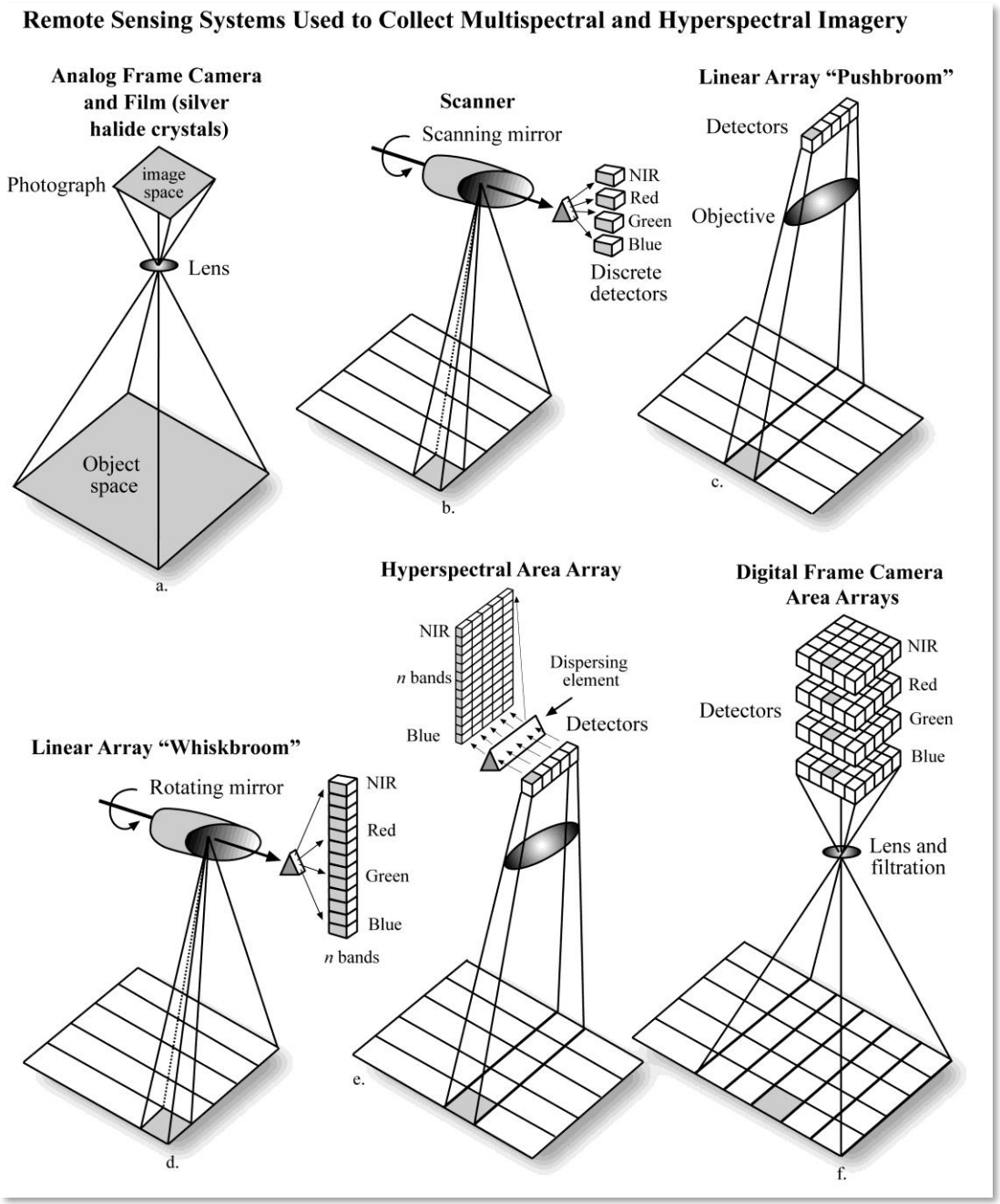
Rozlišovacie schopnosti senzora







- 1. **priestorová** (mm, cm, dc, m, km)
- 2. **spektrálna** (spektrálny rozsah)
  - VID, IČ, termálne, radar
- 3. **rádiometrická** (rozdelenie toku radiácie)
  - elementárna jednotka <0, 255>
- 4. **temporálna** (časový interval 2 záznamov)
  - operatívnosť nosičov – lietadlá, družice

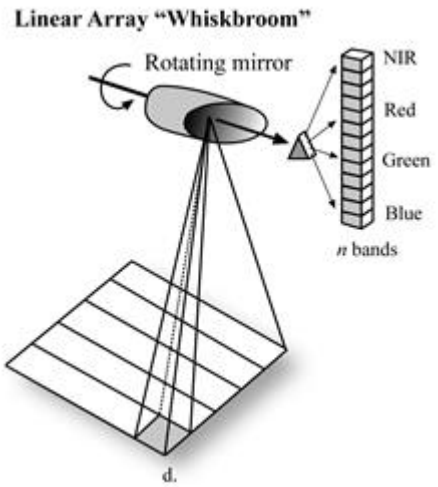


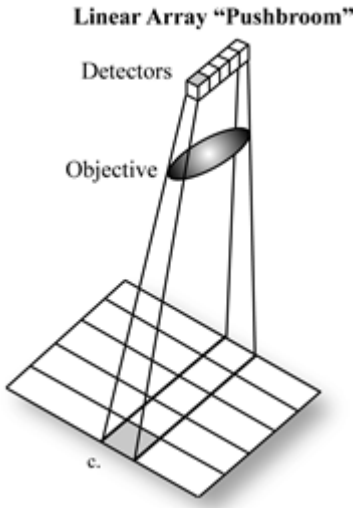
DPZ systémy pre multispektrálne a hyperspektrálne skenovanie

SPOT
LANDSAT
MODIS
SENTINEL 2
IKONOS
GeoEye

Jensen, 2007

Porovnanie LANDSAT 7 ETM+ a LANDSAT 8 OLI/TIRS

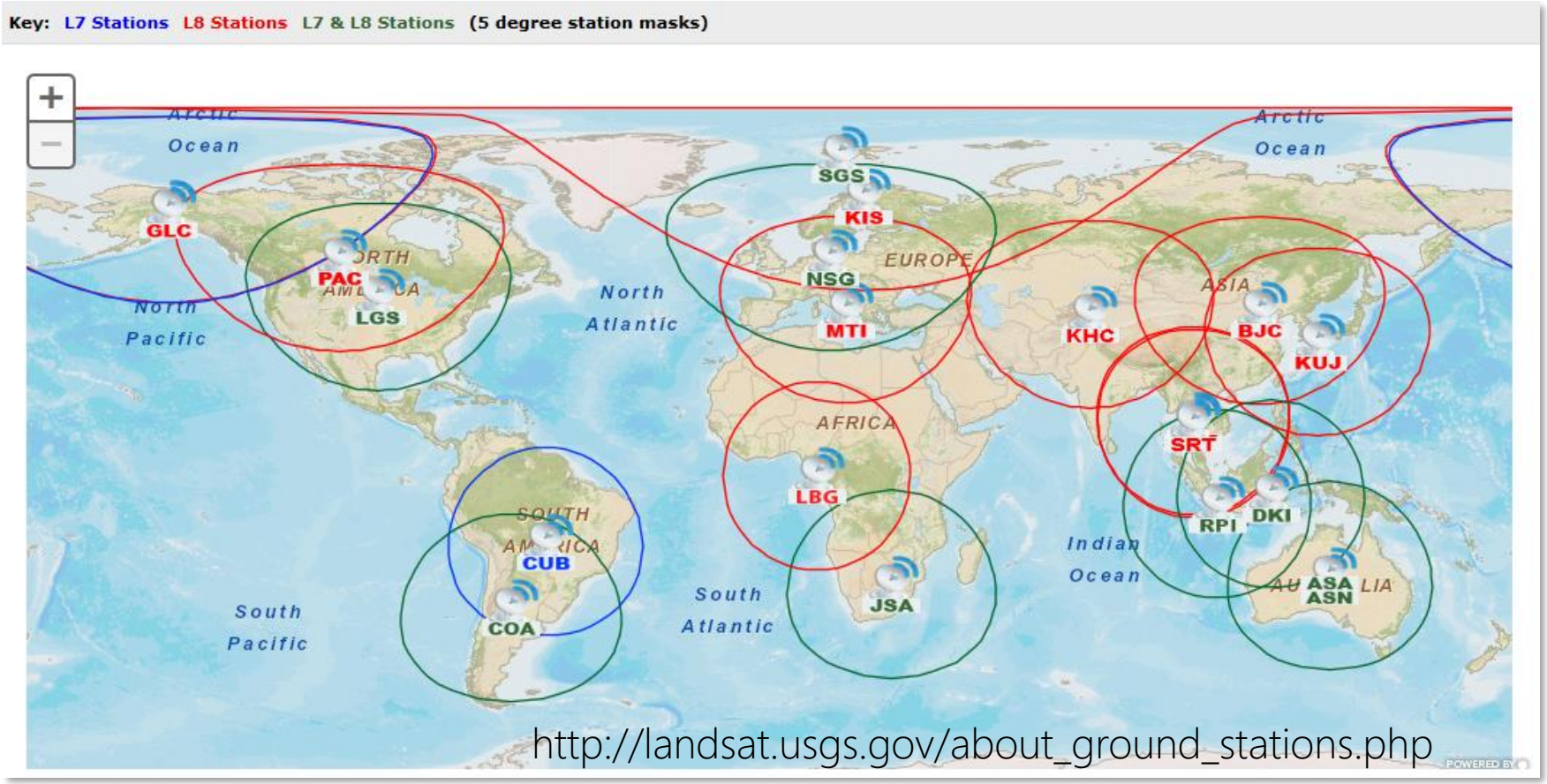




	L7	L8
Scenes/Day	~450	~650
SSR Size	378 Gbits, block-based	3.14 Terabit, file-based
Sensor Type	ETM+, Whisk-Broom	Pushbroom (both OLI and TIRS)
Compression	No	~2:1 Variable Rice Compression
Image D/L	X-Band GXA×3	X-Band Earth Coverage
Data Rate	150 Mbits/sec × 3 Channels/Frequencies	384 Mbits/sec, CCSDS Virtual Channels
Encoding	not fully CCSDS compliant	CCSDS, LDPC FEC
Ranging	S-Band 2-Way Doppler	GPS
Orbit	705 Km Sun-Sync 98.2° inclination (WRS2)	705 Km Sun-Sync 98.2° inclination (WRS2)
Crossing Time	~ 10:00 AM	~ 10:11 AM

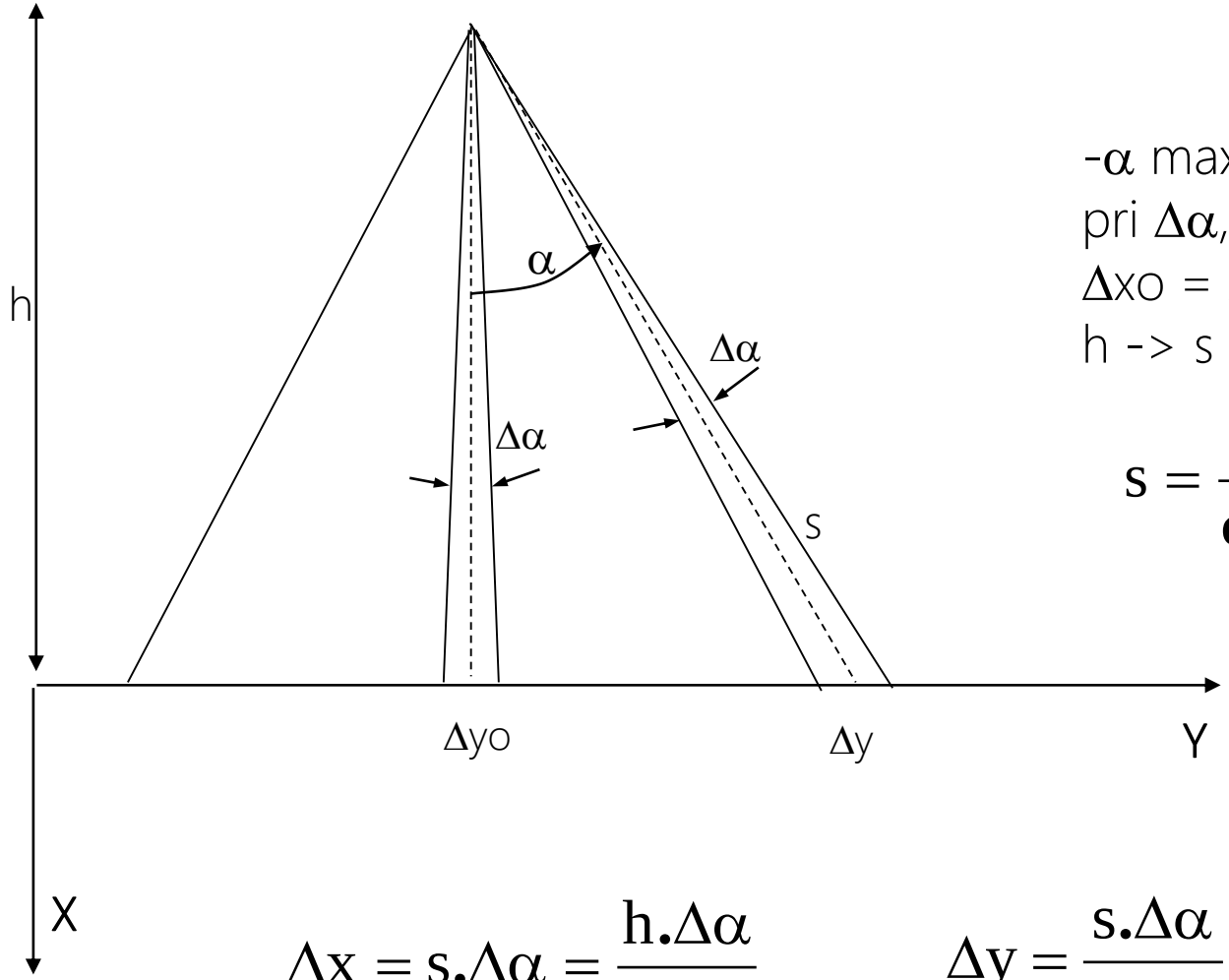
Table 1-1. Comparison of Landsat 7 and Landsat 8 Observatory Capabilities

Pozemné kontrolné stanice družíc LANDSAT



1. Earth Explorer: http://earthexplorere.usgs.gov
2. Global Visualization Viewer: http://glovis.usgs.gov
3. LandsatLook Viewer: http://landsatlook.usgs.gov

Geometria opticko-mechanickéko skenera



-α max až + α max
pri Δα, h Δxo, Δyo
Δxo = Δyo = h . Δ α
h -> s

$$s = \frac{h}{\cos\alpha}$$

$$\Delta x = s.\Delta\alpha = \frac{h.\Delta\alpha}{\cos\alpha}$$

$$\Delta y = \frac{s.\Delta\alpha}{\cos\alpha} = \frac{h.\Delta\alpha}{\cos^2\alpha}$$

Geometria opticko-mechanickéko skenera

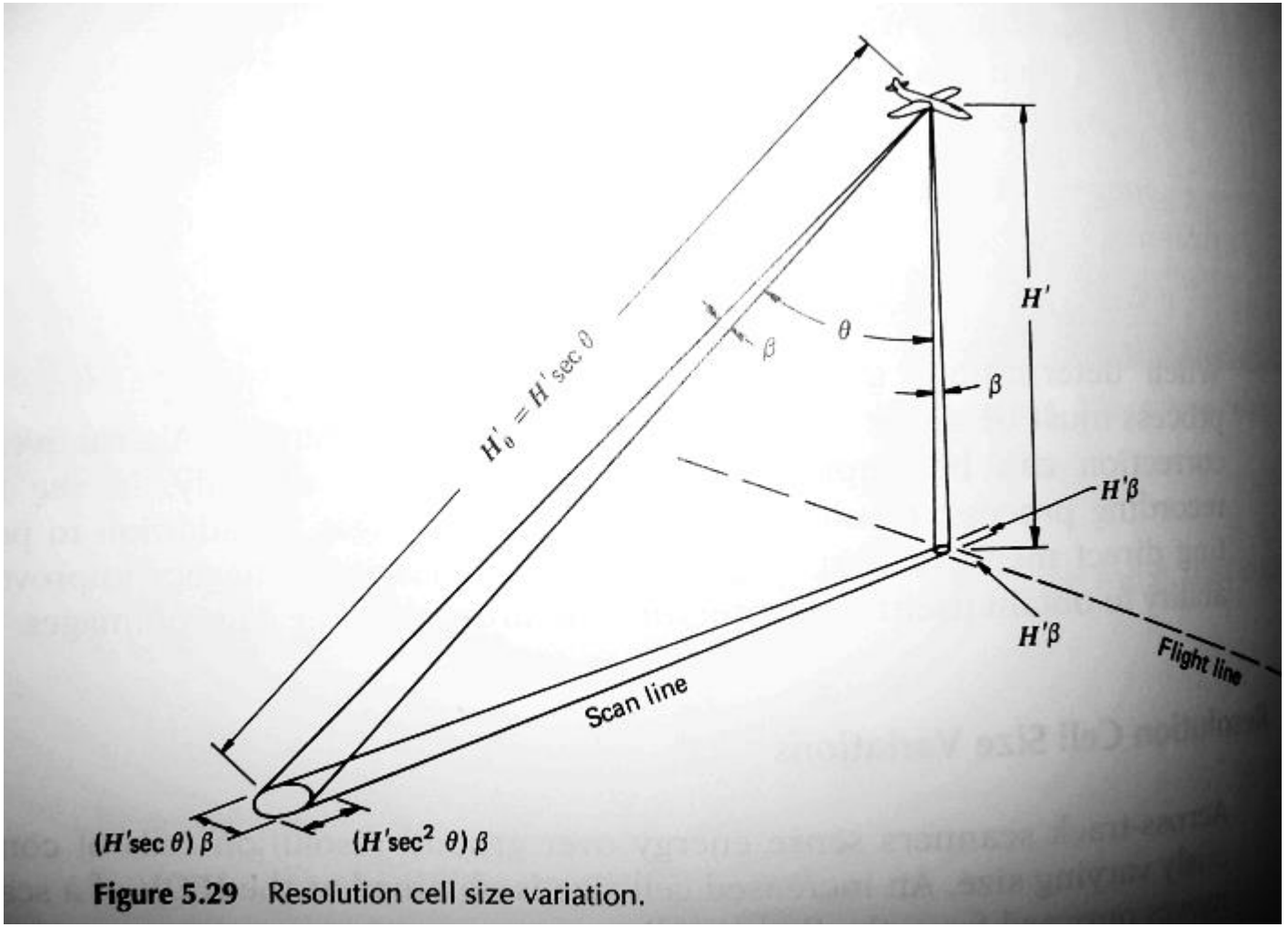
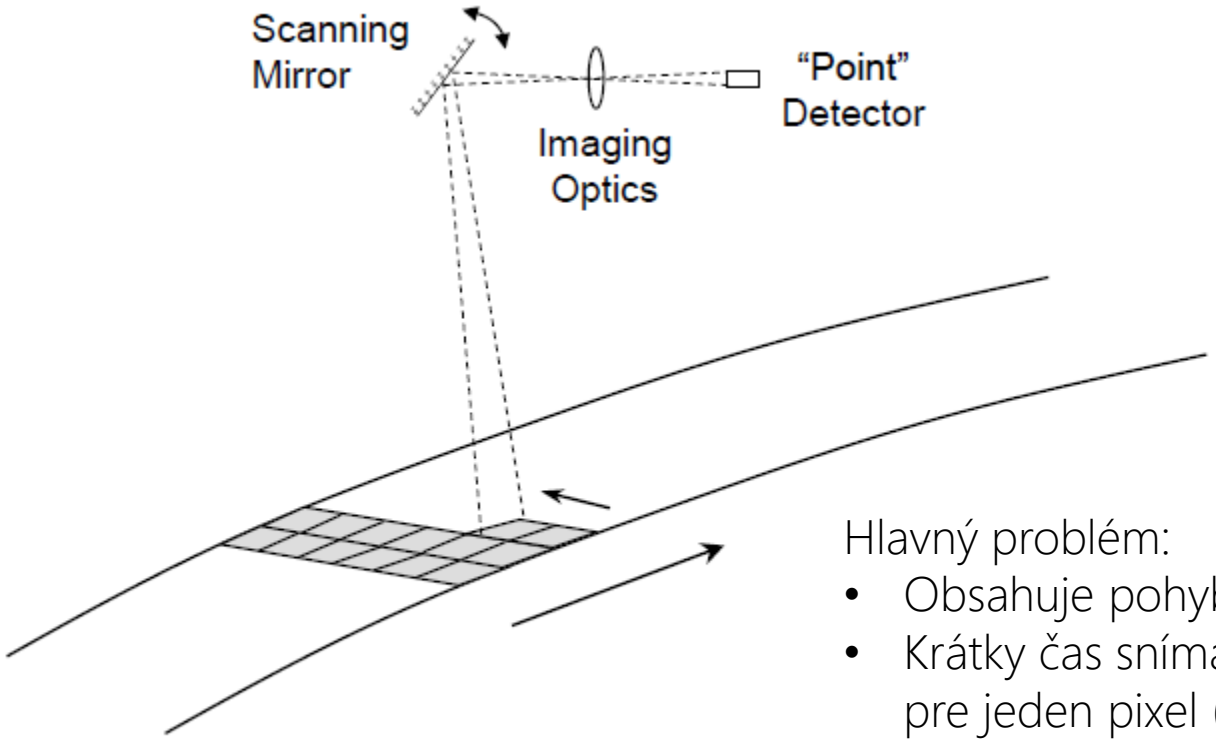


Figure 5.29 Resolution cell size variation.

Geometria opticko-mechanickéko skenera

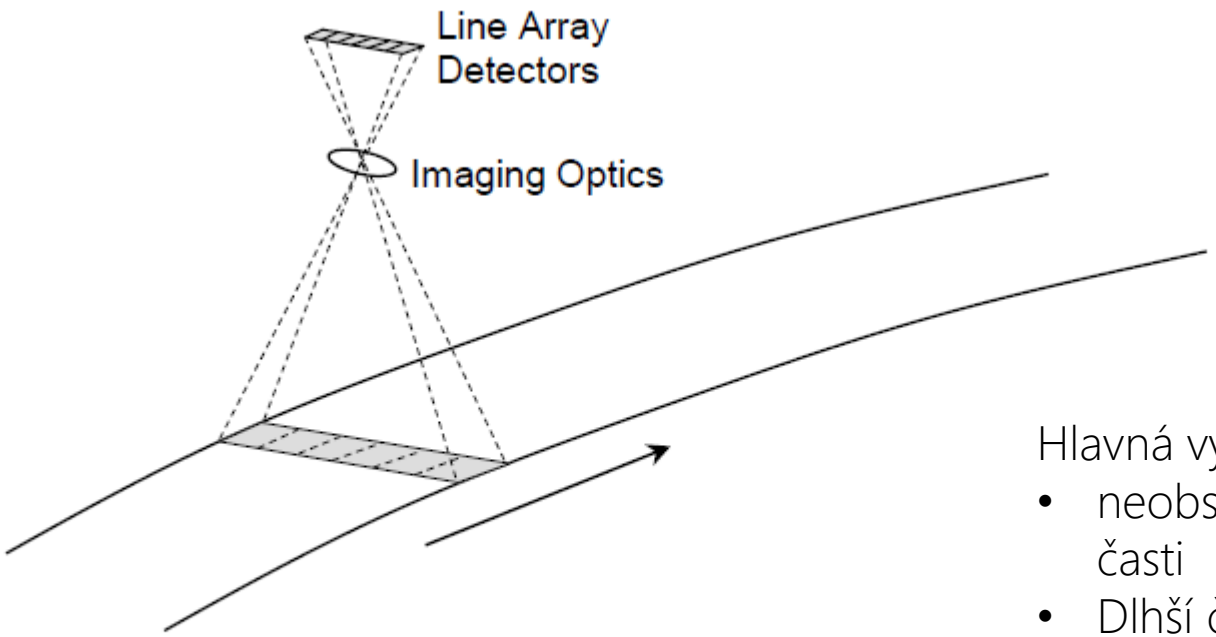


Wiskbroom scanner geometry.

Hlavný problém:

- Obsahuje pohyblivé časti
- Krátky čas snímanie EMŽ pre jeden pixel (nízka citlivosť snímania)

Geometria opticko-elektronického skenera

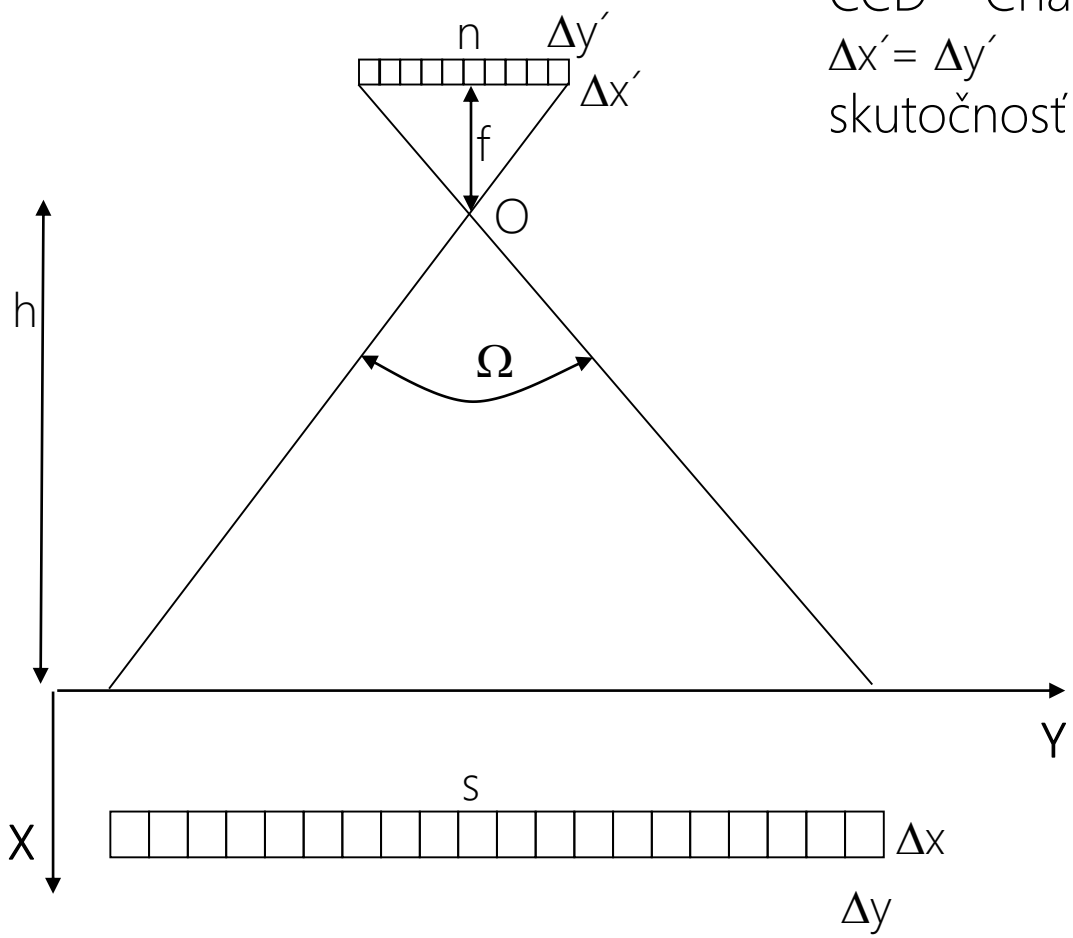


Pushbroom imaging geometry.

Hlavná výhoda:

- neobsahuje pohyblivé časti
- Dlhší čas snímania EMŽ pre jeden pixel (vyššia citlivosť snímania)
- Ostrejší obraz, väčší rozsah hodnôt („farieb“)

Geometria opticko-elektronického skenera



CCD – Charge Coupled Device

$\Delta x' = \Delta y'$

skutočnosť $\Delta x = \Delta y$

$$\Delta y = \Delta y' . \frac{h}{f} \approx \frac{s}{n}$$

ms

$$\Delta x = \Delta t . v$$

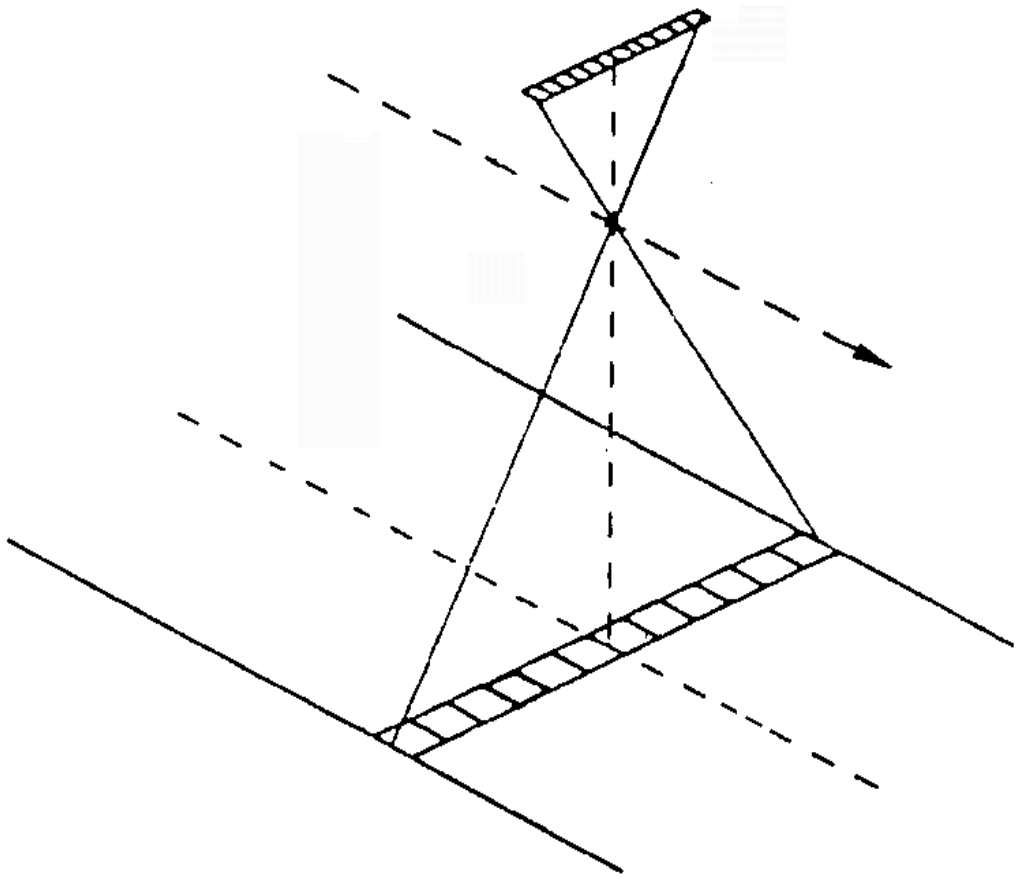
s – šírka stopy na Zemi (swath width)

n – počet pixlov v riadku

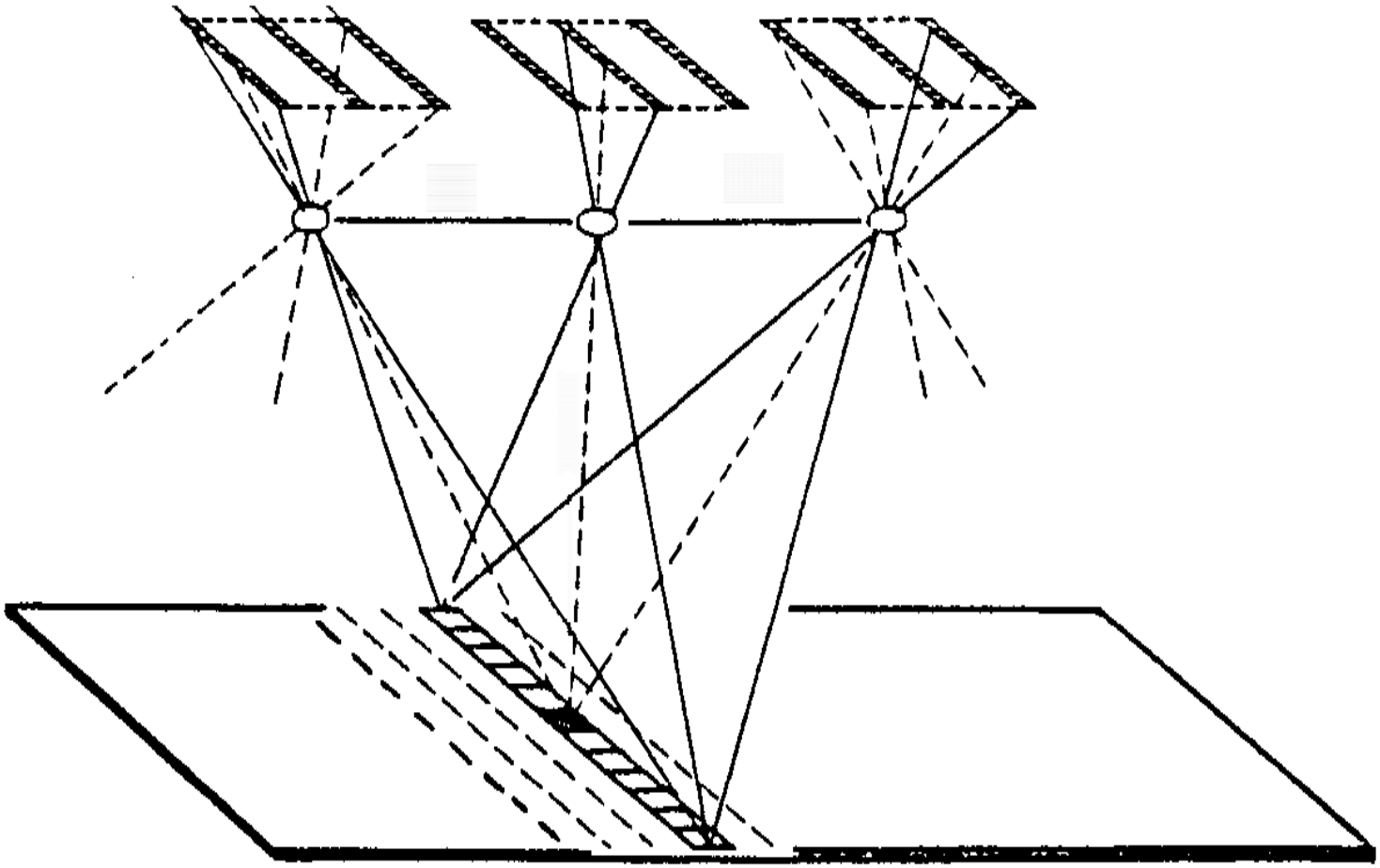
Delta(t) – časový interval snímania jedného riadku

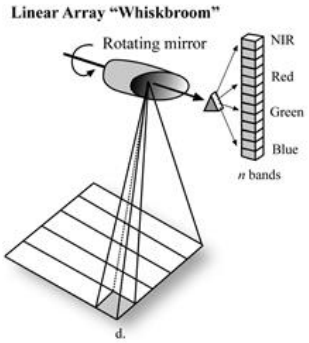
V – rýchlosť letu nad Zemou

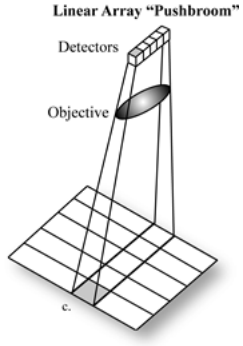
Jednoriadkový skener



Trojriadkový skener







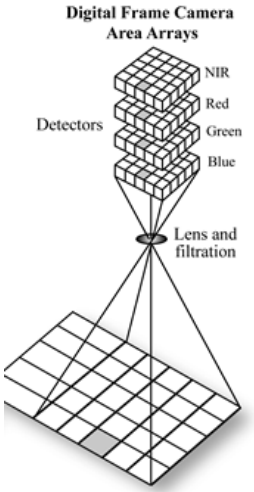
Skener s rotujúcim zrkadlom

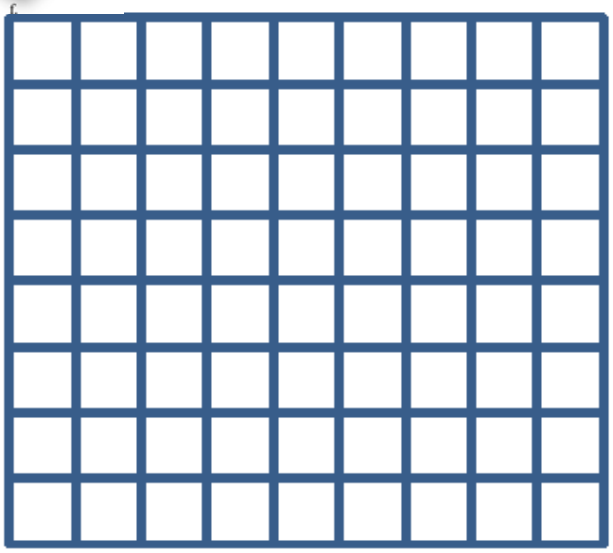
- Zložitejšia tvorba obrazu po pixloch,
- Kratšia doba snímania pre 1 pixel,
- Záznam EMŽ s nižšou citlivosťou, vyžaduje širšie spektrálne pásmo,
- Nižšia geometrická presnosť záznamu,
- Kratšia životnosť DPZ systému.
- Napr. LANDSAT 4 MSS, 5 TM, 7 ETM+

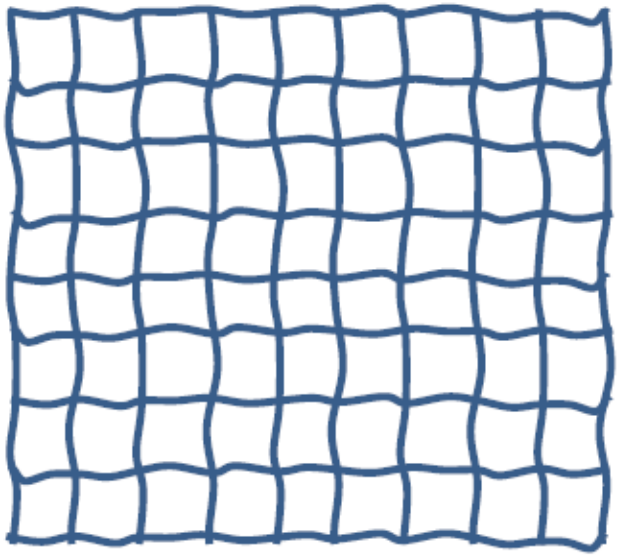
Riadkový skener

- Jednoduchšia tvorba obrazu (po celých riadkoch)
- Dlhšia doba snímania pre jeden pixel
- záznam EMŽ s vyššou citlivosťou, užšie spektrálne pásmo
- Vyššia geometrická presnoť záznamu,
- Dlhšia životnosť.
- Napr. LANDSAT 8 OLI/TIRS, SPOT, ASTER, ALOS, SENTINEL 2,

Plošný snímač (frame camera)

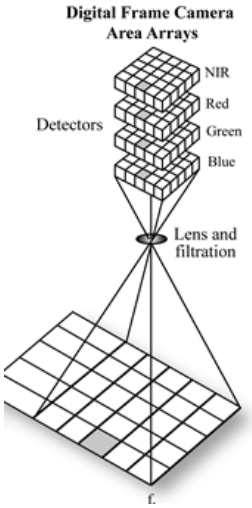


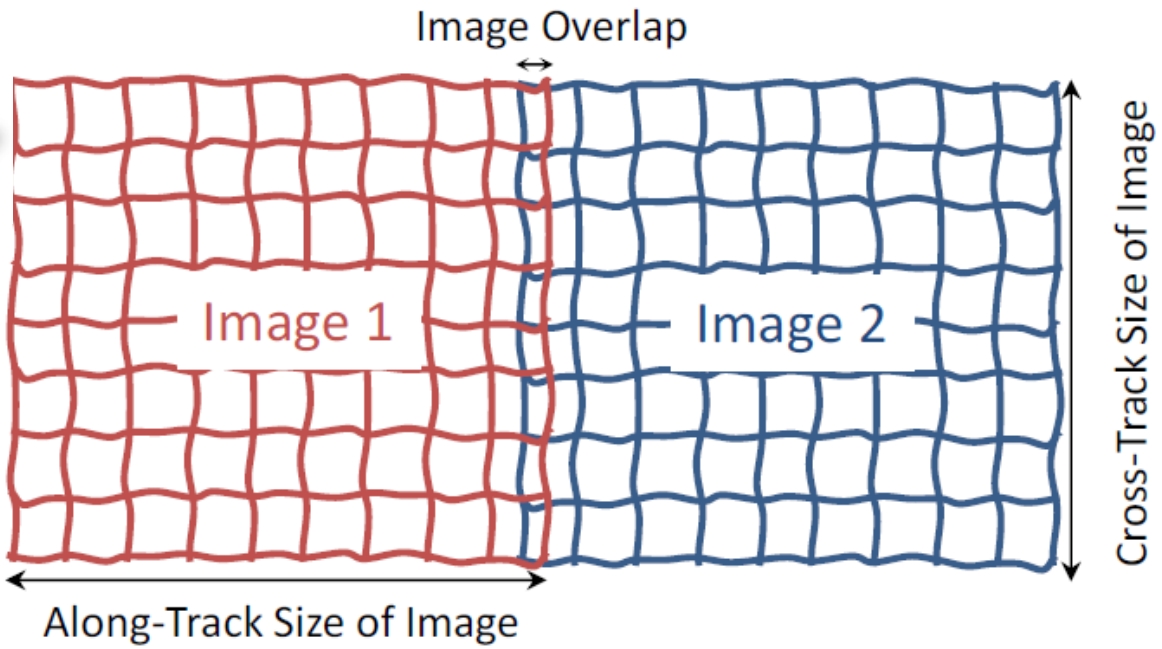




The area on the surface imaged by a framing camera is the projection of the detector array on the surface. If the surface has no relief, the projection will look like the "image" on the left. Local relief distorts the pattern to look more like the "image" on the right.

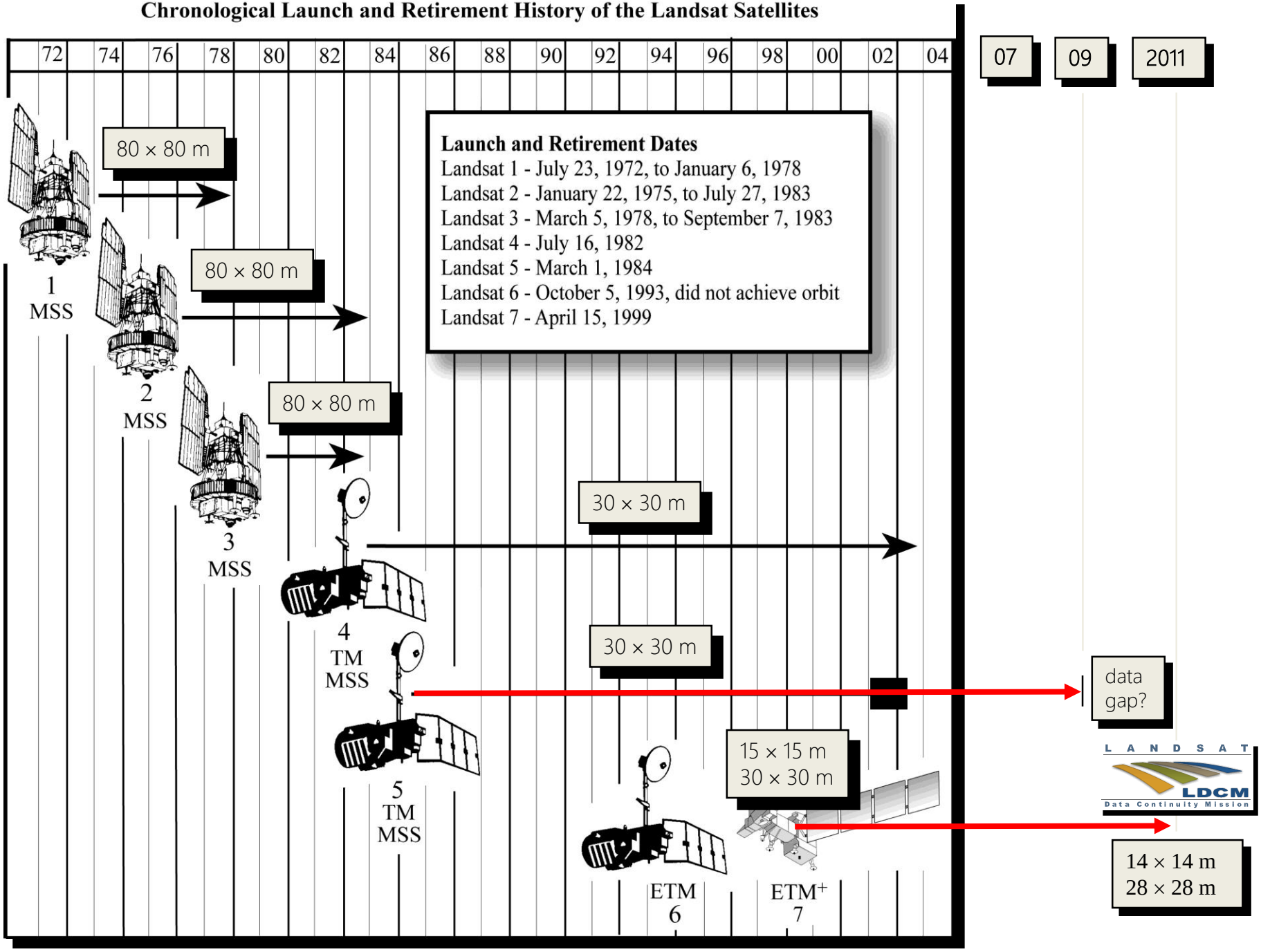
Plošný snímač (frame camera)



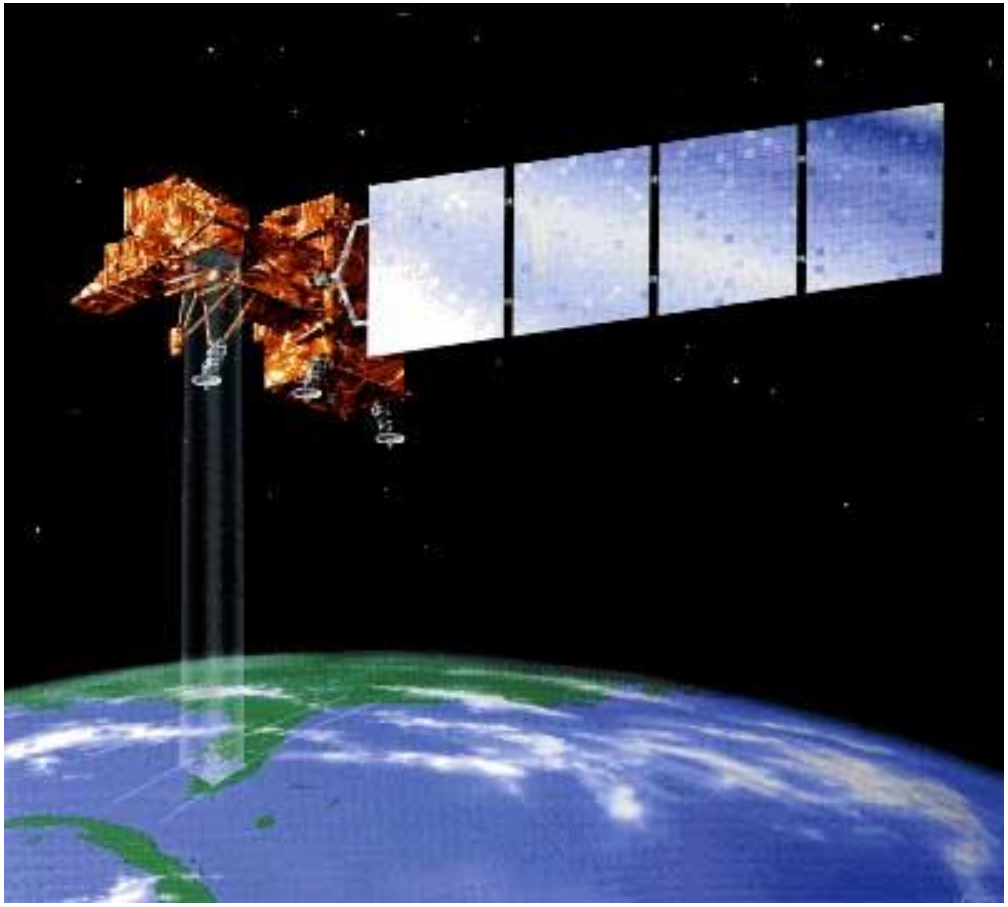


Framing cameras build up strips of images by acquiring successive images in the along-track direction. The images overlap in the along-track direction to ensure that the distortion introduced by the relief does not cause gaps between the images.

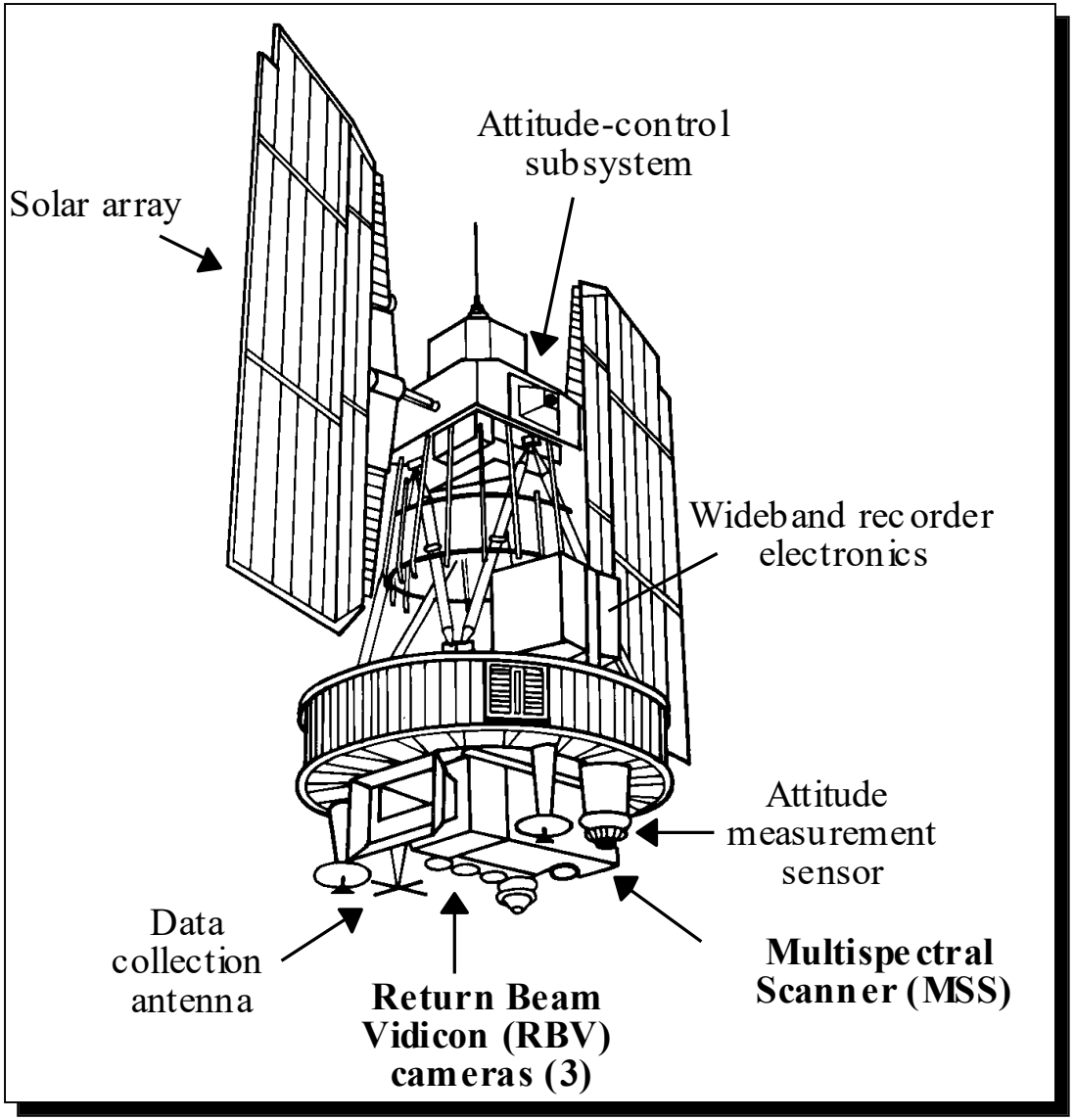
Príklady multispektrálnych skenerov


Chronological Launch and Retirement History of the Landsat Satellites
72
74
76
78
80
82
84
86
88
90
92
94
96
98
00
02
04
07
09
2011
Launch and Retirement Dates
Landsat 1 - July 23, 1972, to January 6, 1978
Landsat 2 - January 22, 1975, to July 27, 1983
Landsat 3 - March 5, 1978, to September 7, 1983
Landsat 4 - July 16, 1982
Landsat 5 - March 1, 1984
Landsat 6 - October 5, 1993, did not achieve orbit
Landsat 7 - April 15, 1999
80 × 80 m
80 × 80 m
80 × 80 m
30 × 30 m
30 × 30 m
15 × 15 m
30 × 30 m
1
MSS
2
MSS
3
MSS
4
TM
MSS
5
TM
MSS
ETM
6
ETM+
7
data
gap?
LANDSAT
LDCM
Data Continuity Mission
14 × 14 m
28 × 28 m

Landsat, SPOT,..

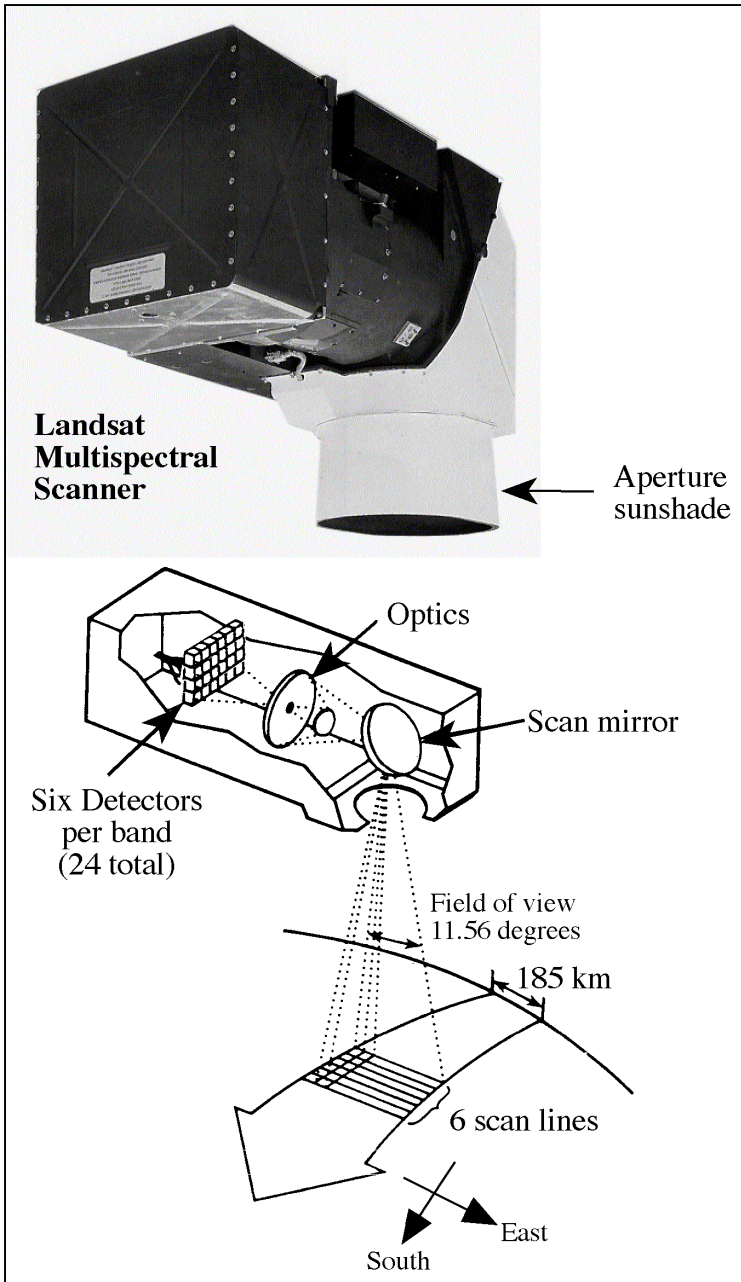


Landsat Multispectral Scanning System (MSS)



Jensen, 2007

Components of the Landsat Multispectral Scanner (MSS) System on Landsat 1 Through 5



Jensen, 2007

Landsat Multispectral Scanner (MSS) and Landsat Thematic Mapper (TM) Sensor System Characteristics

	Landsat Multispectral Scanner (MSS)			Landsat 4 and 5 Thematic Mapper (TM)		
	Band	Spectral Resolution (μm)	Radiometric Sensitivity (NEΔP)[a]	Band	Spectral Resolution (μm)	Radiometric Sensitivity (NEΔP)
	4[b]	0.5 – 0.6	0.57	1	0.45 – 0.52	0.8
	5	0.6 – 0.7	0.57	2	0.52 – 0.60	0.5
	6	0.7 – 0.8	0.65	3	0.63 – 0.69	0.5
	7	0.8 – 1.1	0.70	4	0.76 – 0.90	0.5
	8[c]	10.4 – 12.6	1.4K (NEΔT)	5	1.55 – 1.75	1.0
				6	10.40–12.5	0.5 (NEΔT)
				7	2.08–2.35	2.4
IFOV at nadir	79 × 79 m for bands 4 through 7 240 × 240 m for band 8			30 × 30 m for bands 1 through 5, 7 120 × 120 m for band 6		
Data rate	15 Mb/s			85 Mb/s		
Quantization levels	6 bit (values from 0 to 63)			8 bit (values from 0 to 255)		
Earth coverage	18 days Landsat 1, 2, 3 16 days Landsat 4, 5			16 days Landsat 4, 5		
Altitude	919 km			705 km		
Swath width	185 km			185 km		
Inclination	99°			98.2°		

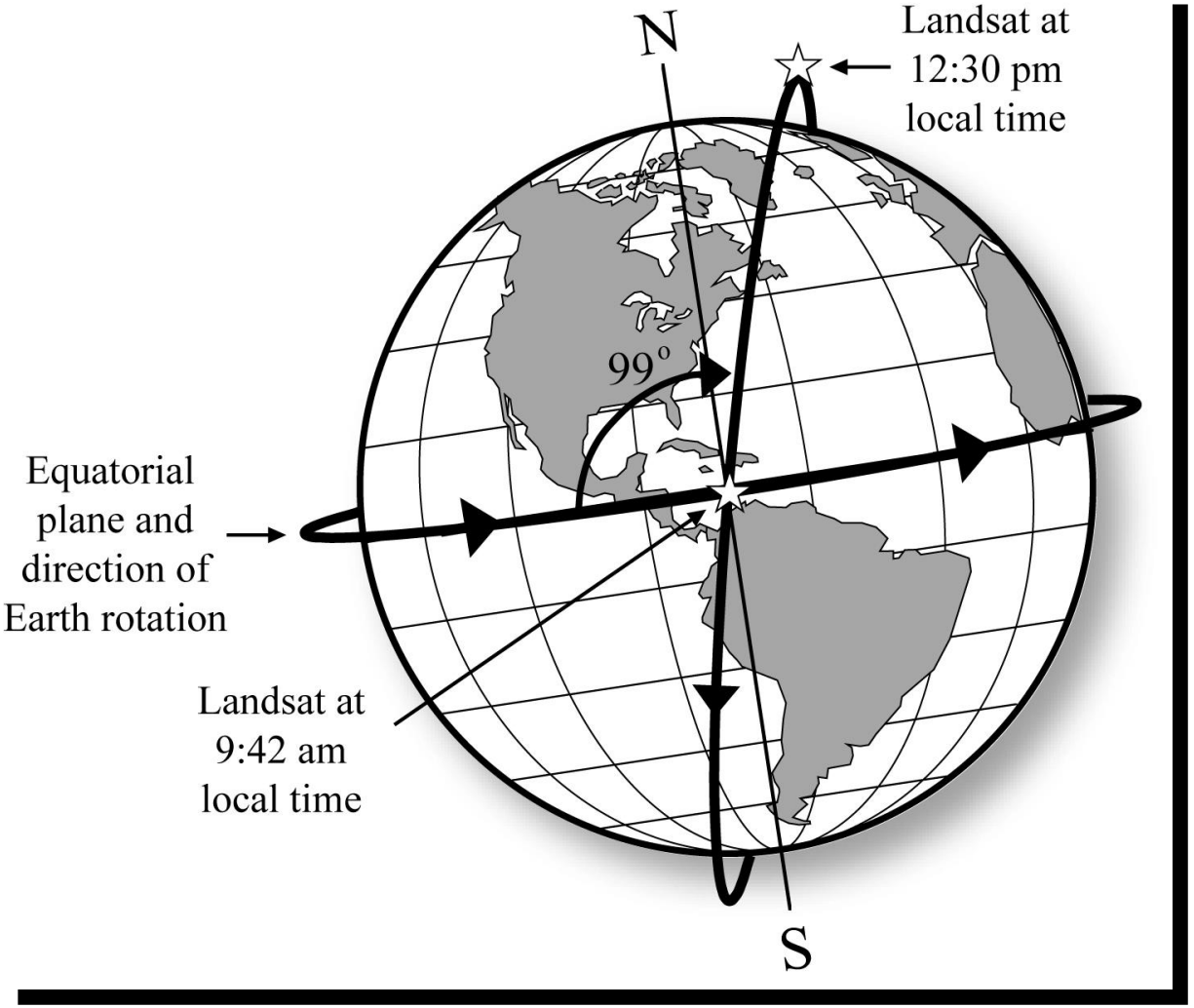
[a] The radiometric sensitivities are the noise-equivalent reflectance differences for the reflective channels expressed as percentages (NEΔP) and temperature differences for the thermal infrared bands (NEΔT).

[b] MSS bands 4, 5, 6, and 7 were renumbered bands 1, 2, 3, and 4 on Landsats 4 and 5.

[c] MSS band 8 was present only on Landsat 3.

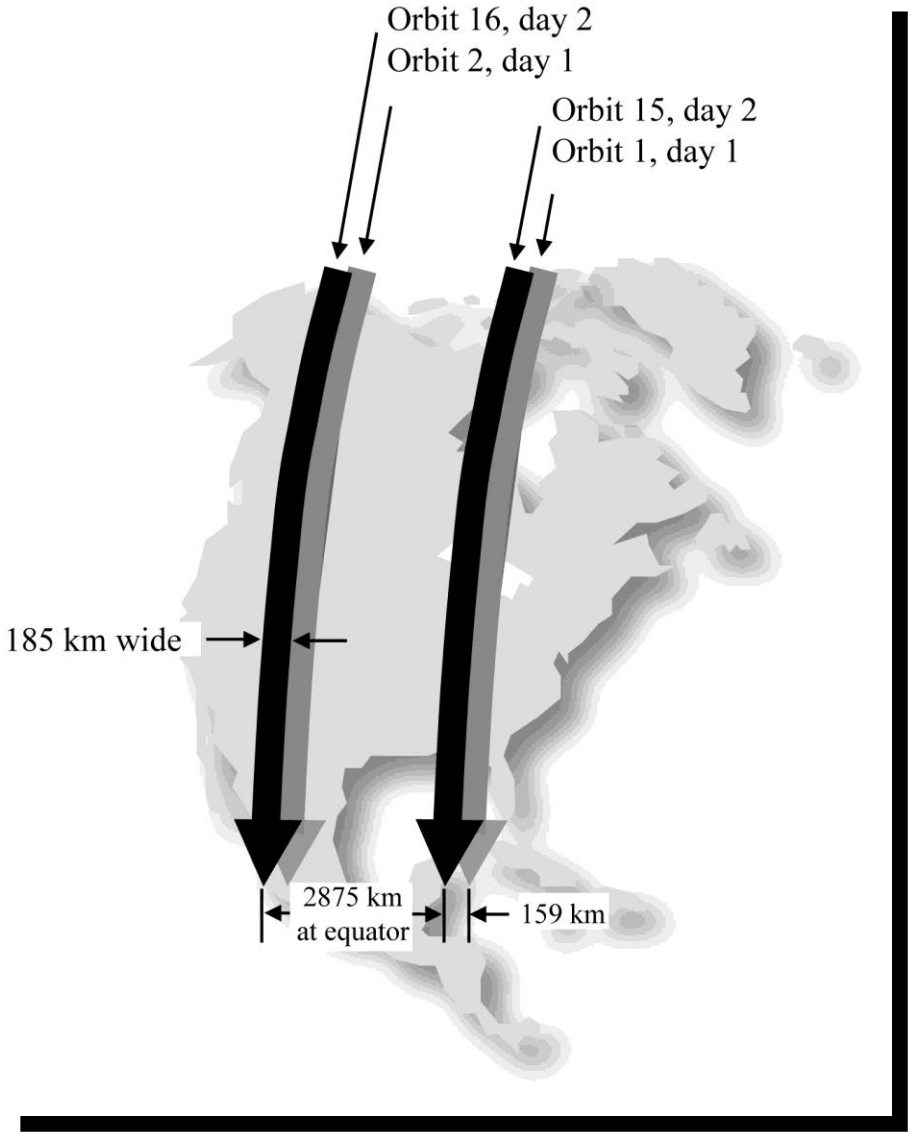
Jensen, 2007

Inclination of the Landsat Orbit to Maintain A Sun-synchronous Orbit



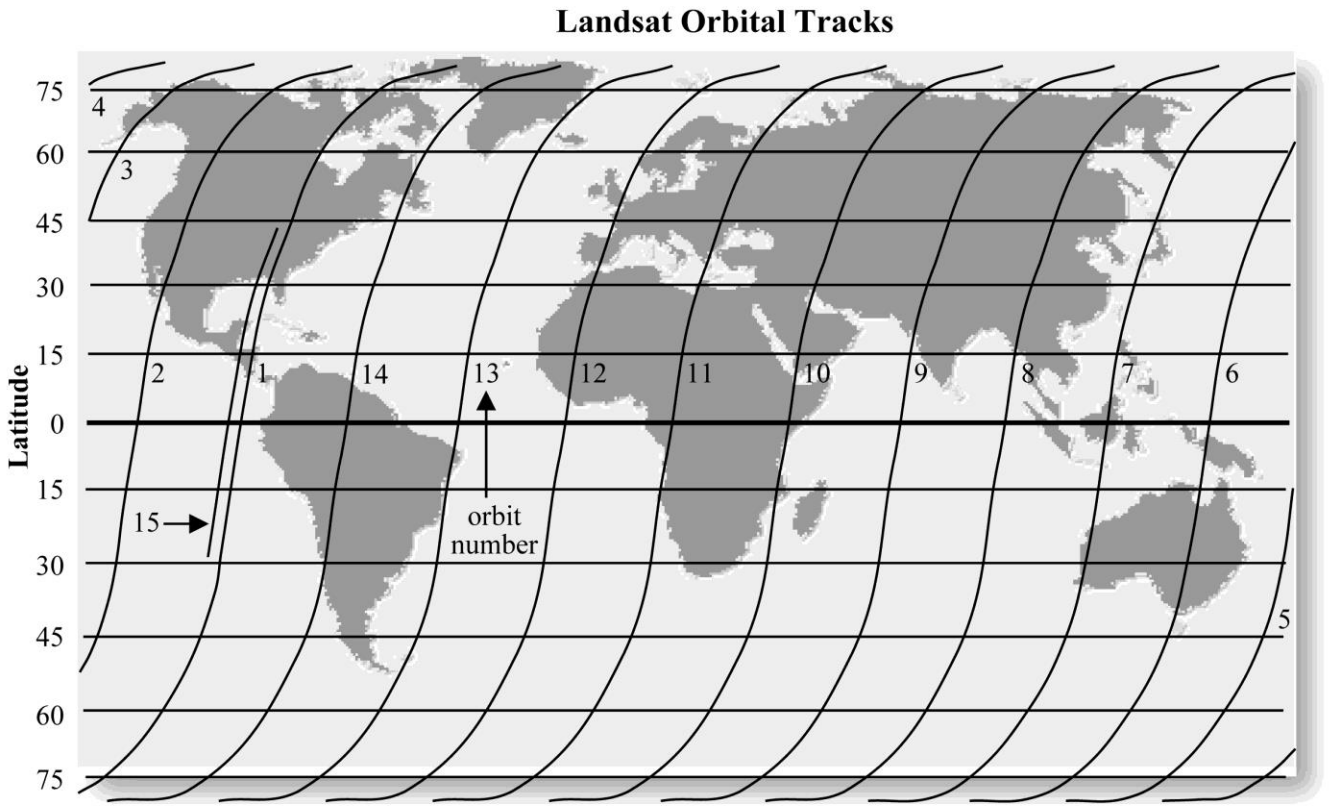
Jensen, 2007

Landsat Multispectral Scanning System (MSS) Orbit

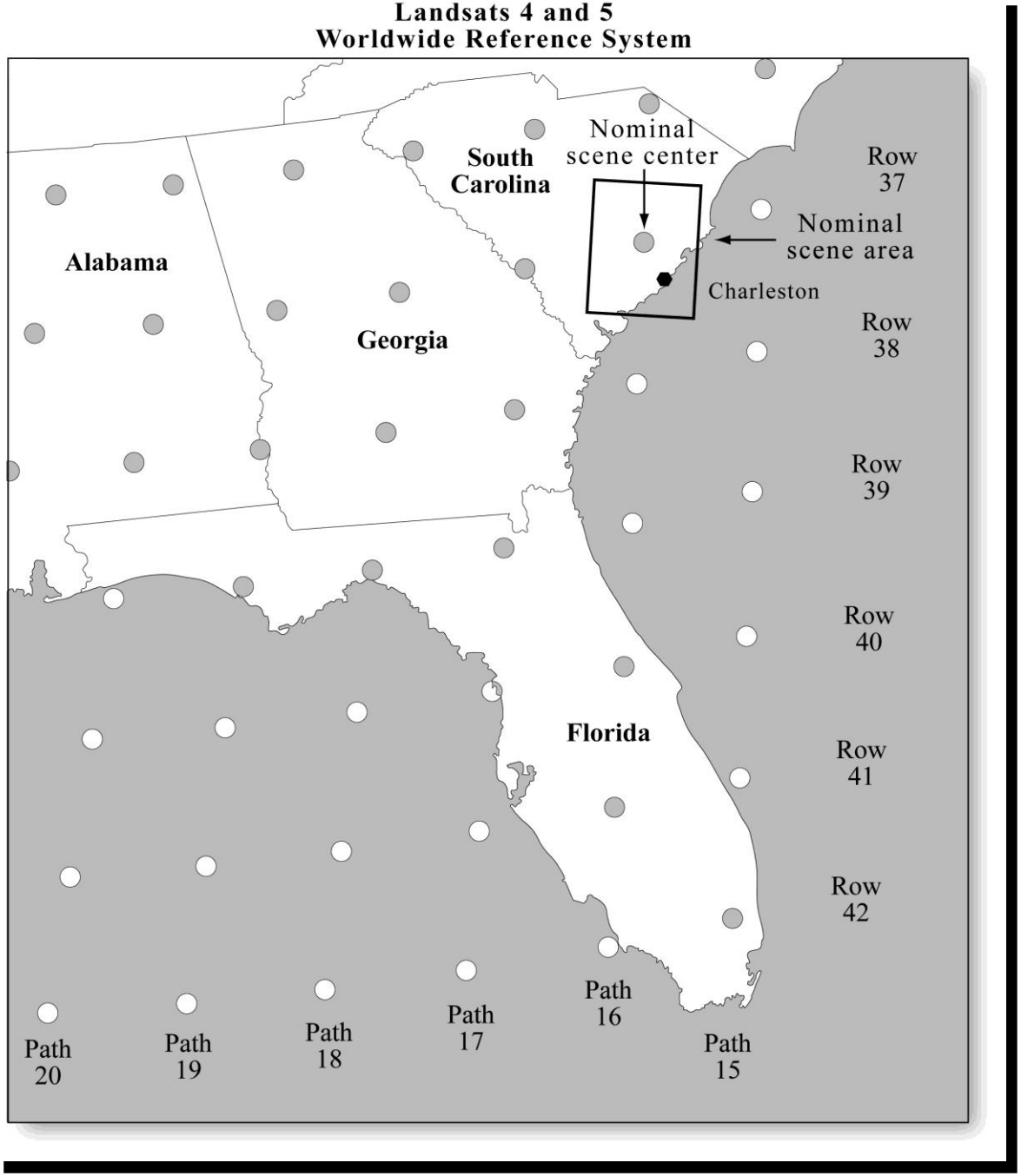


Jensen, 2007

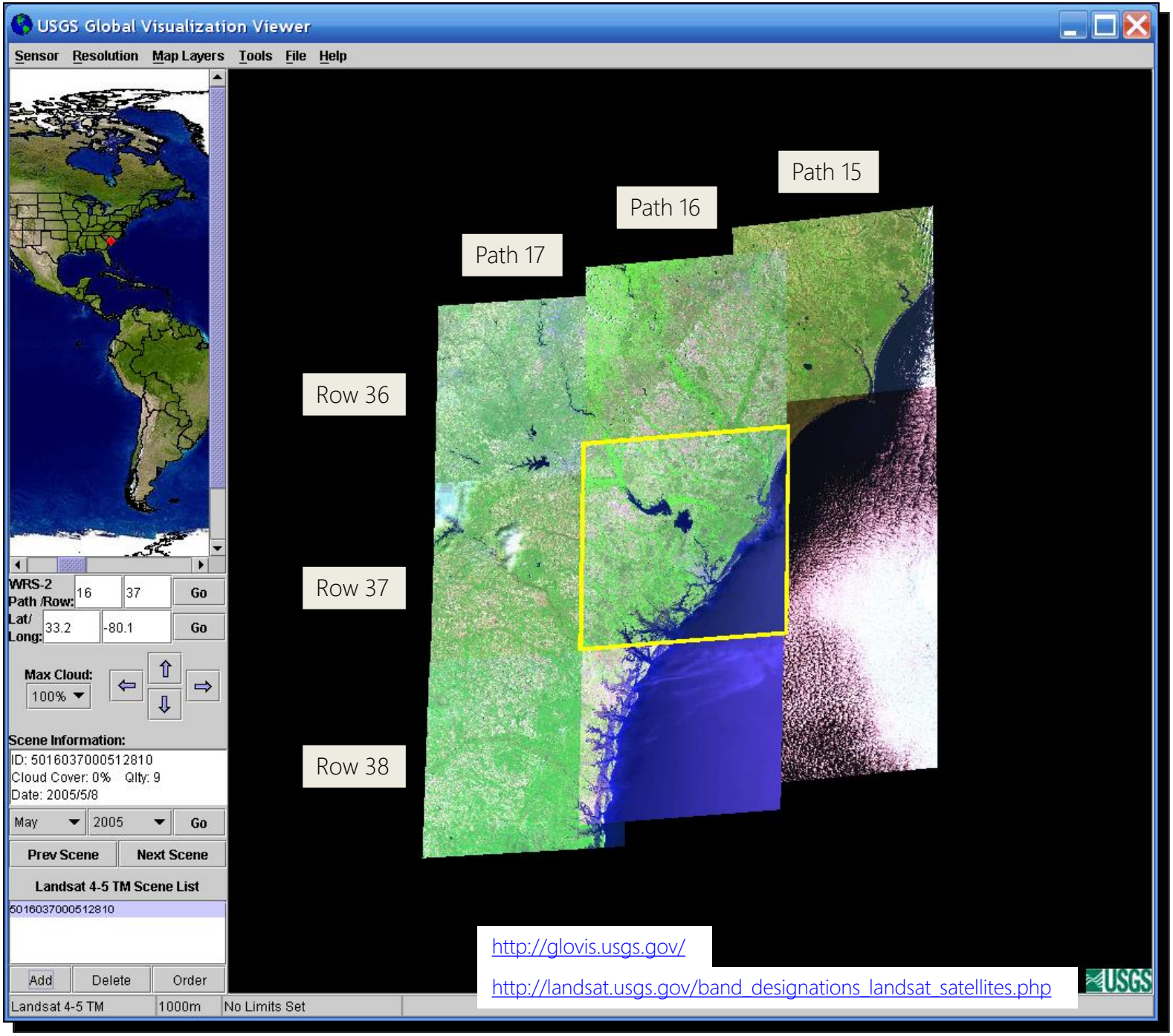
Orbit Tracks of Landsat 1, 2, or 3 During A Single Day of Coverage



Jensen, 2007


Landsats 4 and 5
Worldwide Reference System
South Carolina
Nominal scene center
Nominal scene area
Charleston
Alabama
Georgia
Florida
Row 37
Row 38
Row 39
Row 40
Row 41
Row 42
Path 20
Path 19
Path 18
Path 17
Path 16
Path 15

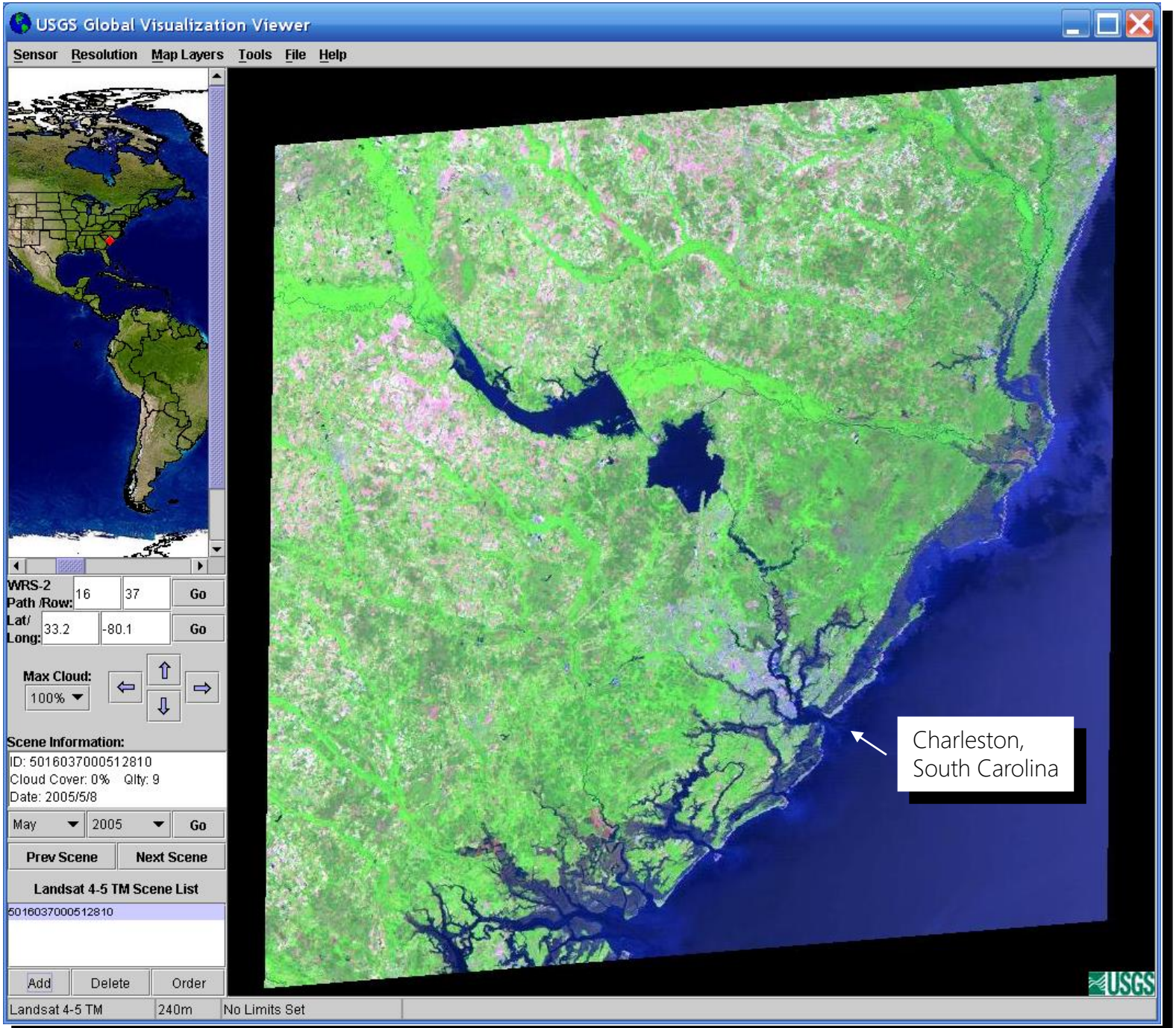
Jensen, 2007



http://glovis.usgs.gov/

http://landsat.usgs.gov/band_designations_landsat_satellites.php

Jensen, 2007


USGS Global Visualization Viewer
Sensor
Resolution
Map Layers
Tools
File
Help
WRS-2 Path /Row:
16
37
Go
Lat/ Long:
33.2
-80.1
Go
Max Cloud:
100%
Scene Information:
ID: 5016037000512810
Cloud Cover: 0% Qlty: 9
Date: 2005/5/8
May
2005
Go
Prev Scene
Next Scene
Landsat 4-5 TM Scene List
5016037000512810
Add
Delete
Order
Landsat 4-5 TM
240m
No Limits Set
Charleston, South Carolina
USGS

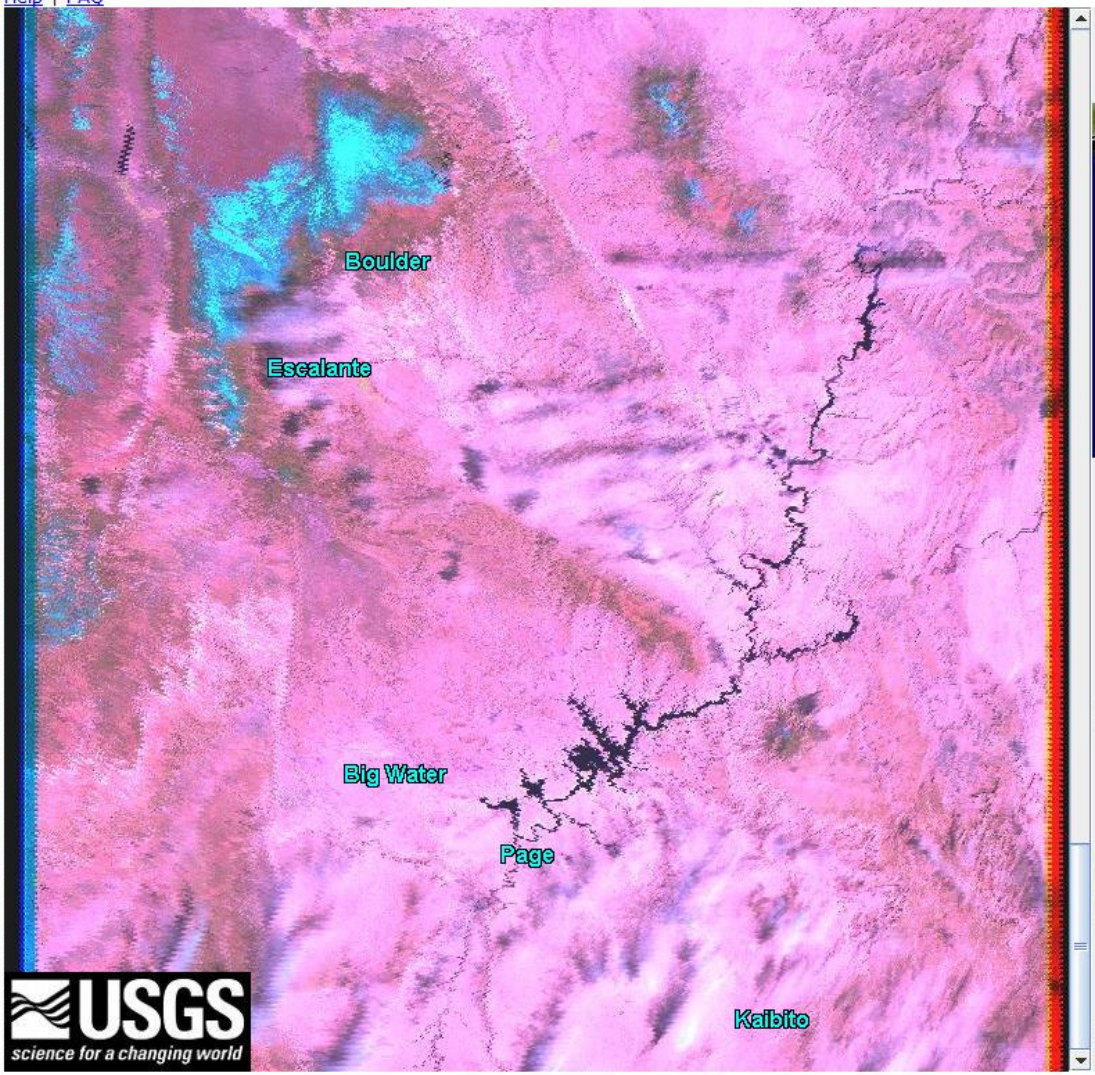
Jensen, 2007

Firefox | USGS Global Visualization Viewer | EarthNow! Landsat Image Viewer | Technical Details « Landsat Science | What are the band designations f

earthnow.usgs.gov/earthnow_app.html?sessionId=d22c64ff4f585e6764d6f57a6022bcf159400

Most Visited | Getting Started | UPJŠ | Gmail | sciencedirect | SHMU | Google Translate | web gallay | MIV portal | jedalen UPJS | Google Maps | SJR citatio

Help | FAQ



EarthNow!

Landsat Image Viewer

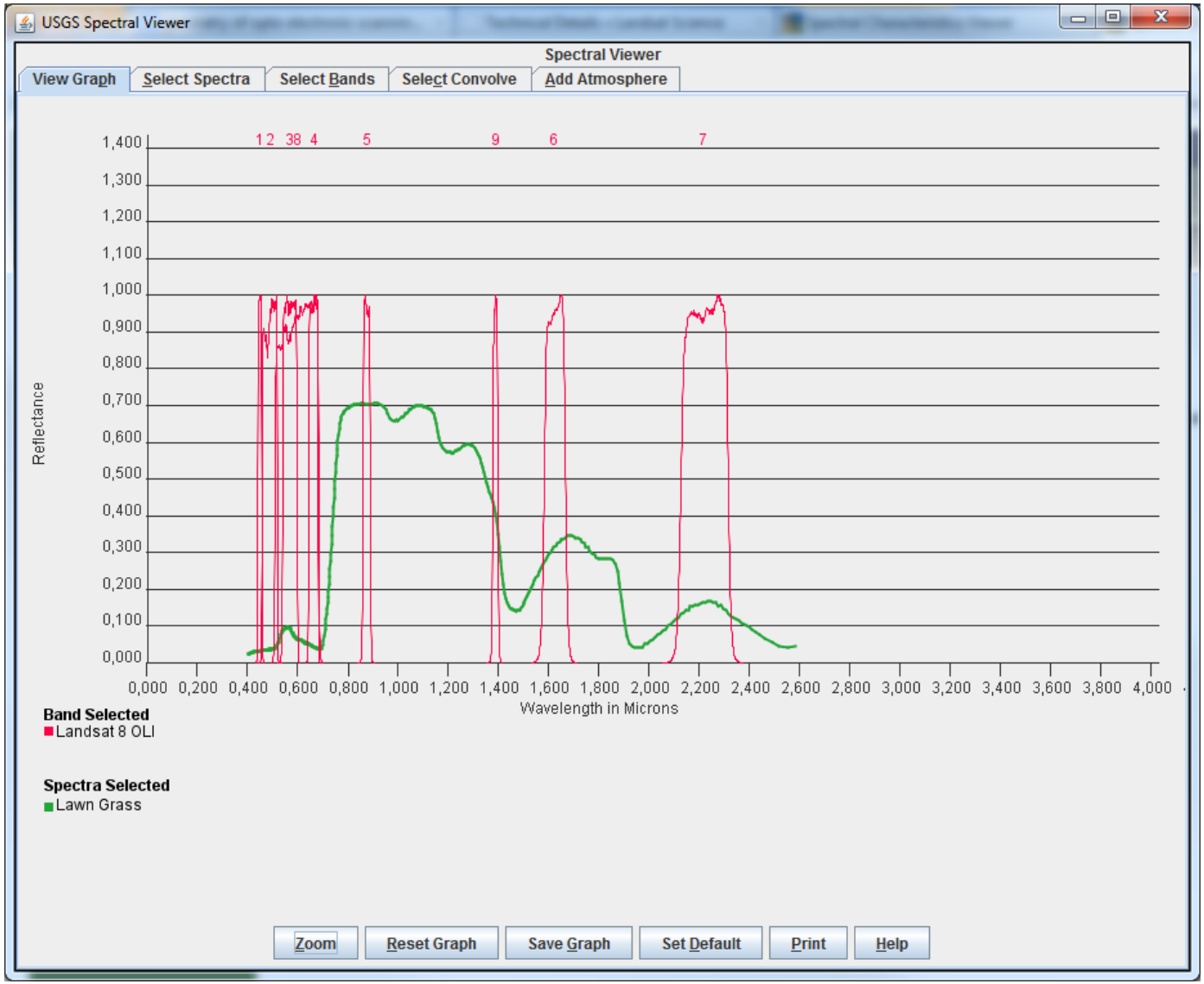
Now Showing: Landsat 7
Replay
Acquired: 8:00pm 10-Apr

Next Pass: Unknown

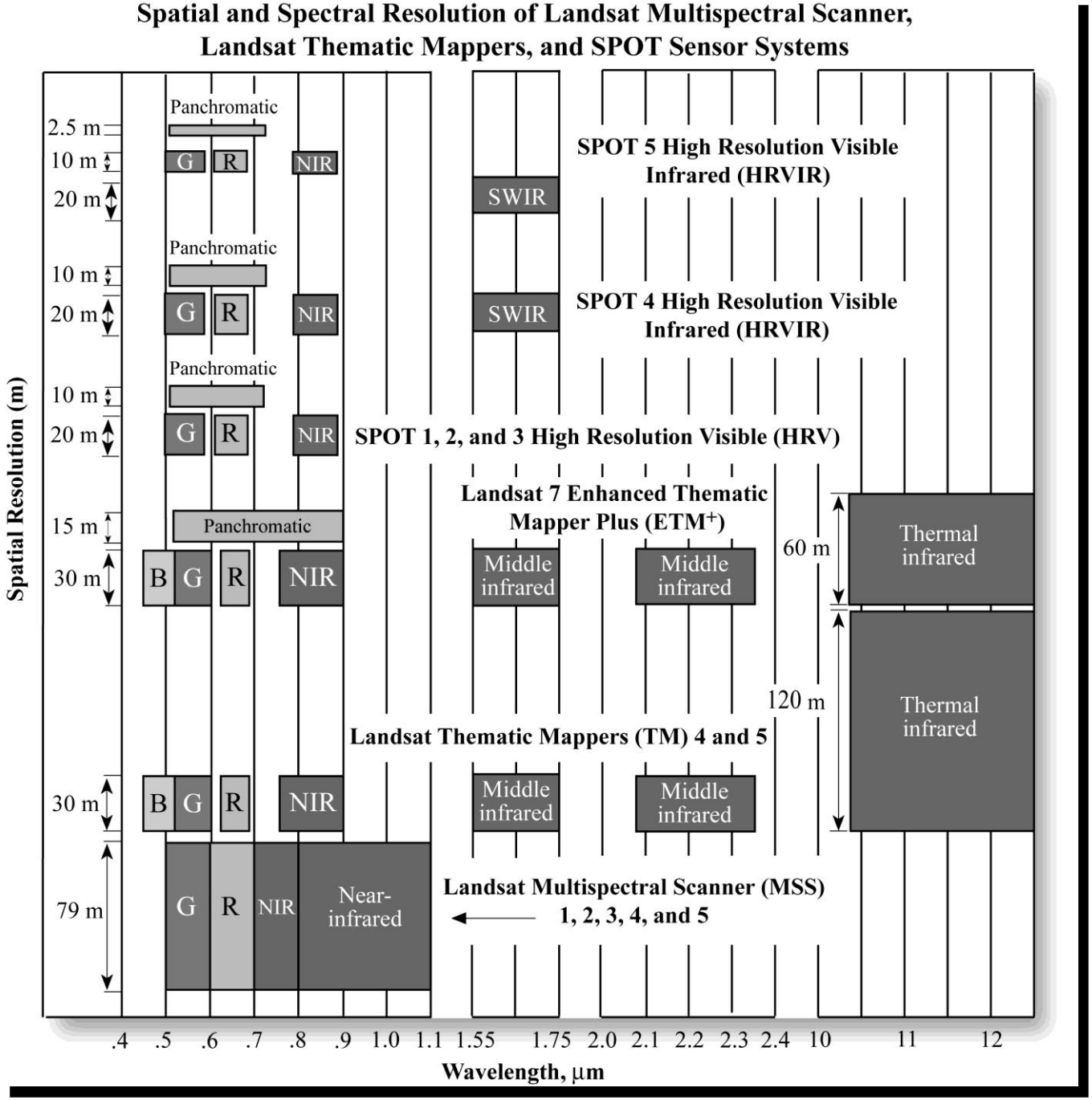
Landsat 7 scenes over the U.S. are available for download within 24 hours of acquisition at http://glovis.usgs.gov.

Landsat satellites have been acquiring images of the Earth's land surface since 1972. Currently there are more than 3 million Landsat images in the National Satellite Land Remote Sensing Data Archive. For more information about Landsat visit http://landsat.usgs.gov.

Acquired at the U.S. Geological Survey Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD

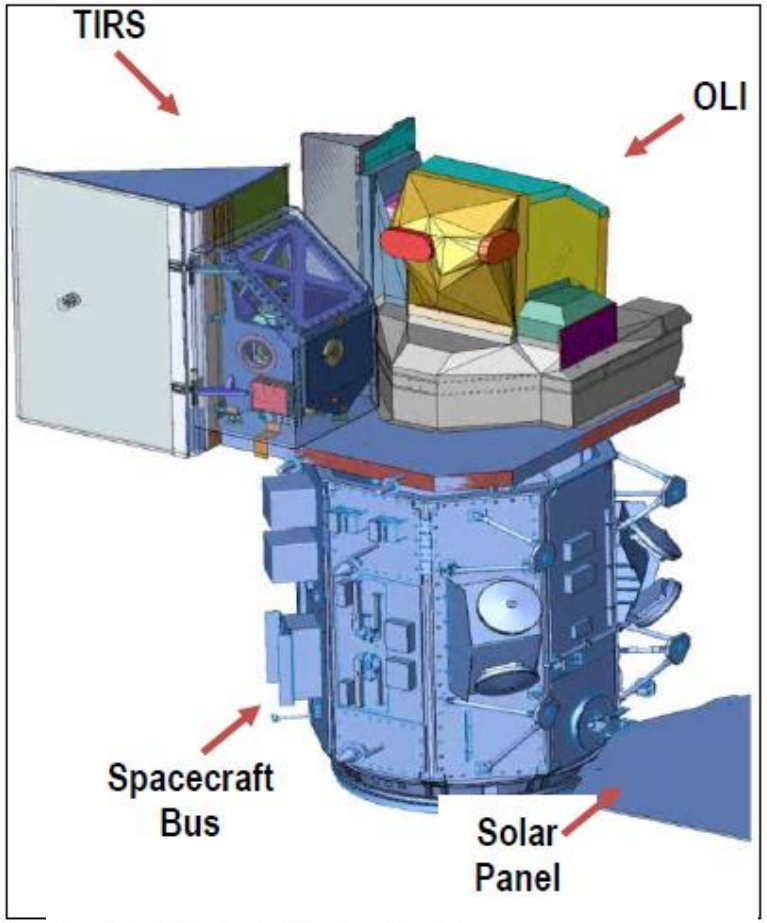


http://landsat.usgs.gov/tools_viewer.php


Spatial and Spectral Resolution of Landsat Multispectral Scanner, Landsat Thematic Mappers, and SPOT Sensor Systems
Spatial Resolution (m)
2.5 m
10 m
20 m
Panchromatic
G
R
NIR
SWIR
SPOT 5 High Resolution Visible Infrared (HRVIR)
10 m
20 m
Panchromatic
G
R
NIR
SWIR
SPOT 4 High Resolution Visible Infrared (HRVIR)
10 m
20 m
Panchromatic
G
R
NIR
SPOT 1, 2, and 3 High Resolution Visible (HRV)
Landsat 7 Enhanced Thematic Mapper Plus (ETM+)
15 m
Panchromatic
30 m
B
G
R
NIR
Middle infrared
Middle infrared
60 m
Thermal infrared
120 m
Thermal infrared
Landsat Thematic Mappers (TM) 4 and 5
30 m
B
G
R
NIR
Middle infrared
Middle infrared
79 m
G
R
NIR
Near-infrared
Landsat Multispectral Scanner (MSS) 1, 2, 3, 4, and 5
.4 .5 .6 .7 .8 .9 1.0 1.1 1.55 1.75 2.0 2.1 2.2 2.3 2.4 10 11 12
Wavelength, μm

Jensen, 2007

LANDSAT 8 OLI/TIRS



LANDSAT 8 (L8)
DATA USERS HANDBOOK

2.2 Operational Land Imager (OLI)

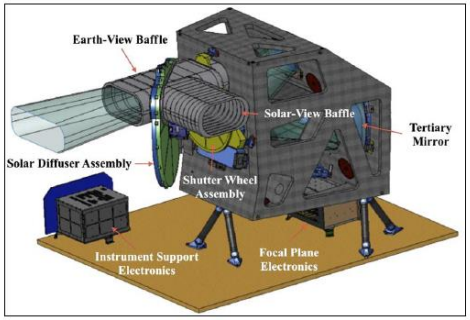


Figure 2-2. OLI Instrument

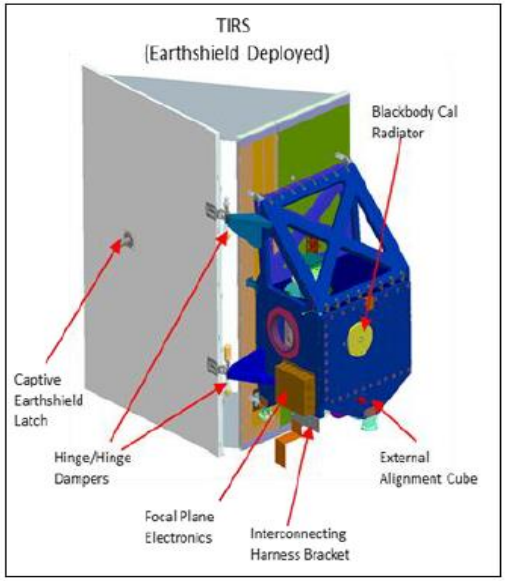


Figure 2-6. TIRS Instrument with Earthshield Deployed

LANDSAT 8 OLI/TIRS

Landsat-7 ETM+ Bands (µm)			Landsat-8 OLI and *TIRS* Bands (µm)		
			30 m Coastal/Aerosol	0.435 - 0.451	Band 1
Band 1	30 m Blue	0.441 - 0.514	30 m Blue	0.452 - 0.512	Band 2
Band 2	30 m Green	0.519 - 0.601	30 m Green	0.533 - 0.590	Band 3
Band 3	30 m Red	0.631 - 0.692	30 m Red	0.636 - 0.673	Band 4
Band 4	30 m NIR	0.772 - 0.898	30 m NIR	0.851 - 0.879	Band 5
Band 5	30 m SWIR-1	1.547 - 1.749	30 m SWIR-1	1.566 - 1.651	Band 6
Band 6	60 m TIR	10.31 - 12.36	*100 m TIR-1*	*10.60 – 11.19*	Band 10
			100 m TIR-2	*11.50 – 12.51*	Band 11
Band 7	30 m SWIR-2	2.064 - 2.345	30 m SWIR-2	2.107 - 2.294	Band 7
Band 8	15 m Pan	0.515 - 0.896	15 m Pan	0.503 - 0.676	Band 8
			30 m Cirrus	1.363 - 1.384	Band 9

Table 2-1. OLI and TIRS Spectral Bands Compared to ETM+ Spectral Bands

Ďalšie

- Sentinel 2
- ASTER
- MODIS (Terra/Aqua)
- GeoEye
- WorldView
- IKONOS
- SPOT
- QuickBird

Sentinel 2A (Red=B2, Green=B3, Blue=B4), cell=10m, Košice, 17. feb. 2016

LANDSAT 8 (Red=B4, Green=B3, Blue=B2), cell=30m, Košice, 6. august 2015