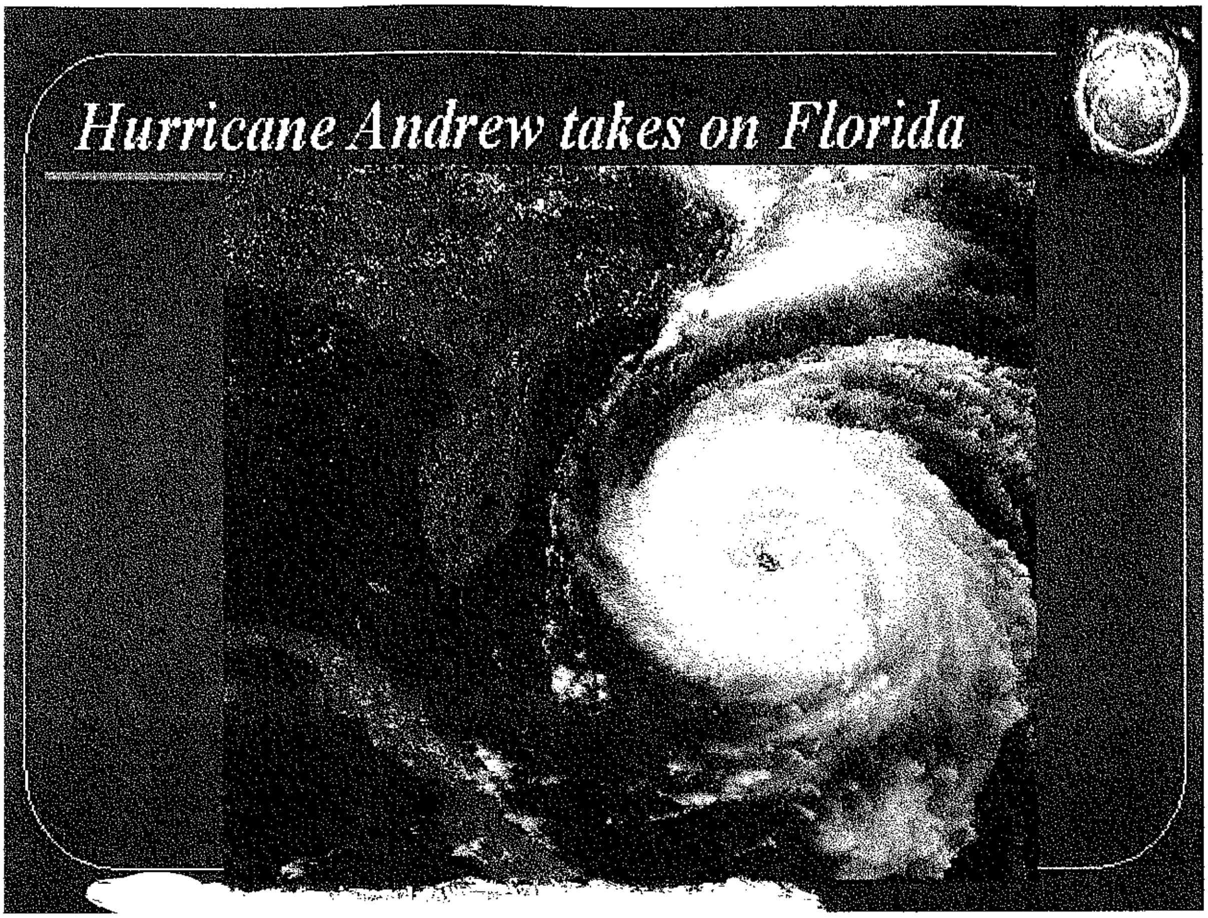
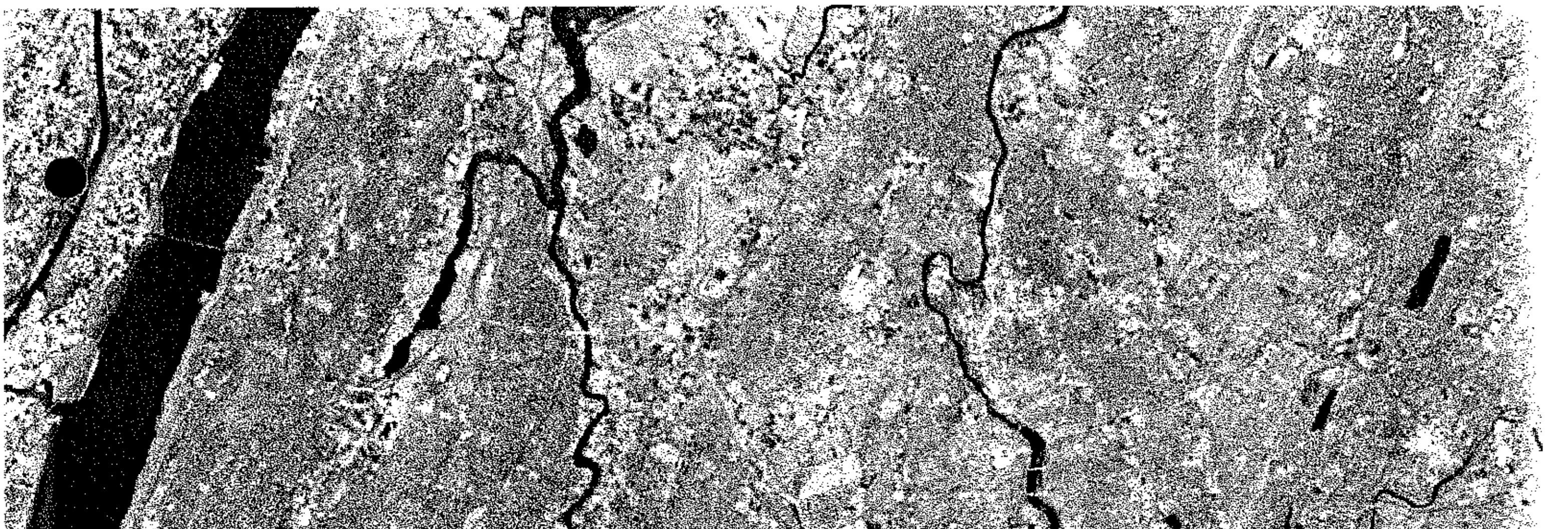
1

(2)

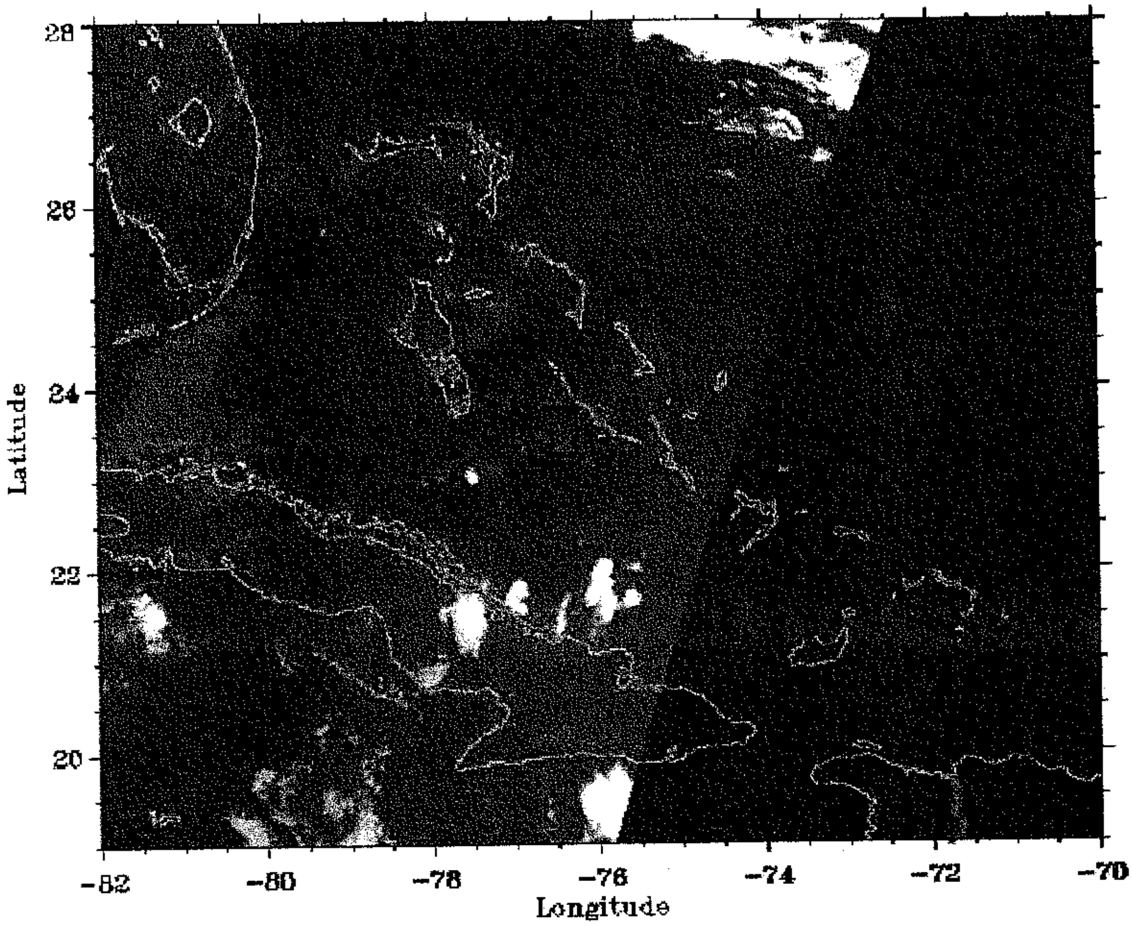


12

1



Bahamas



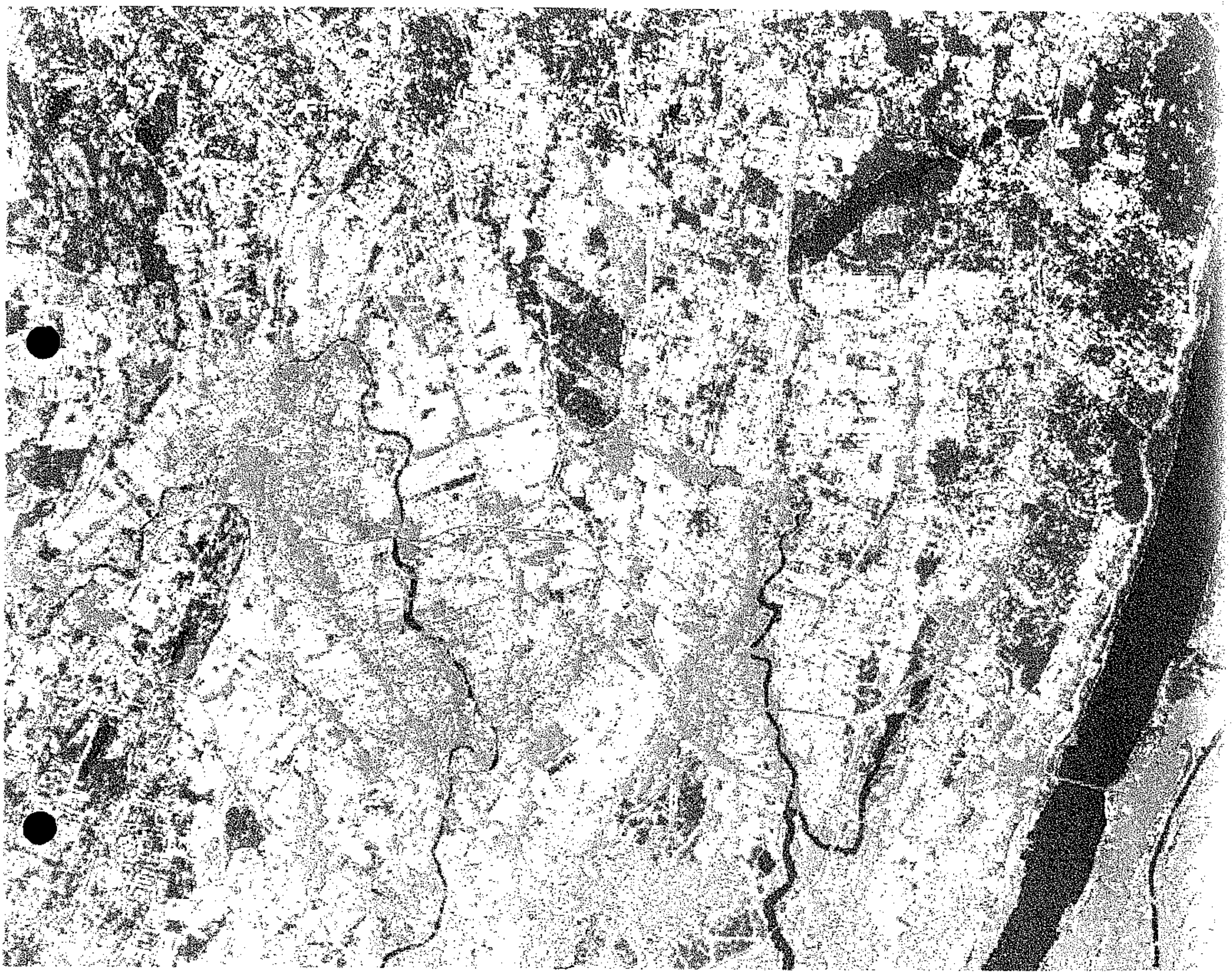
AVHRR Channel 4 image

NOAA–12 AVHRR 2002 Oct 04 10:43 UT

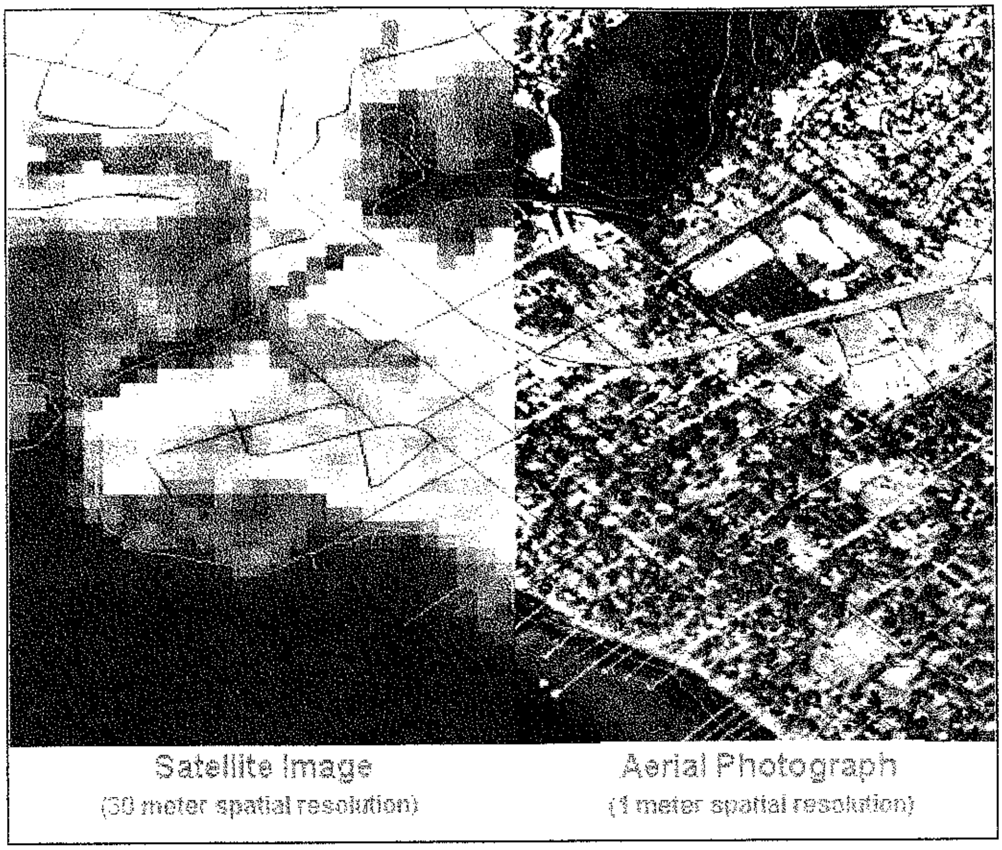
Nighttime: –C4

2)

(2)

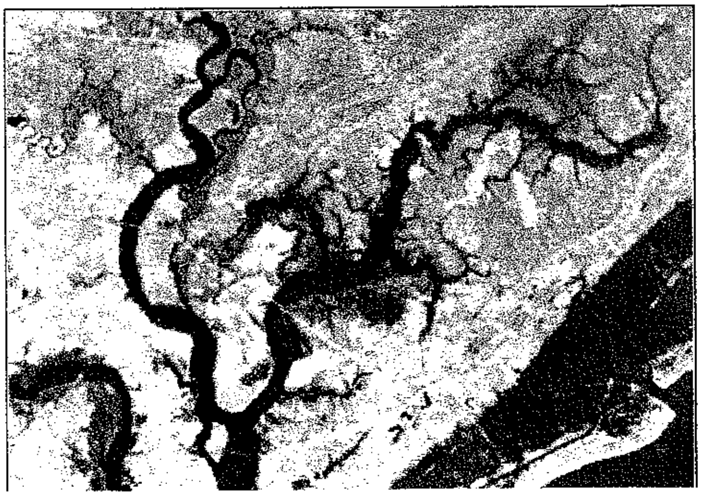


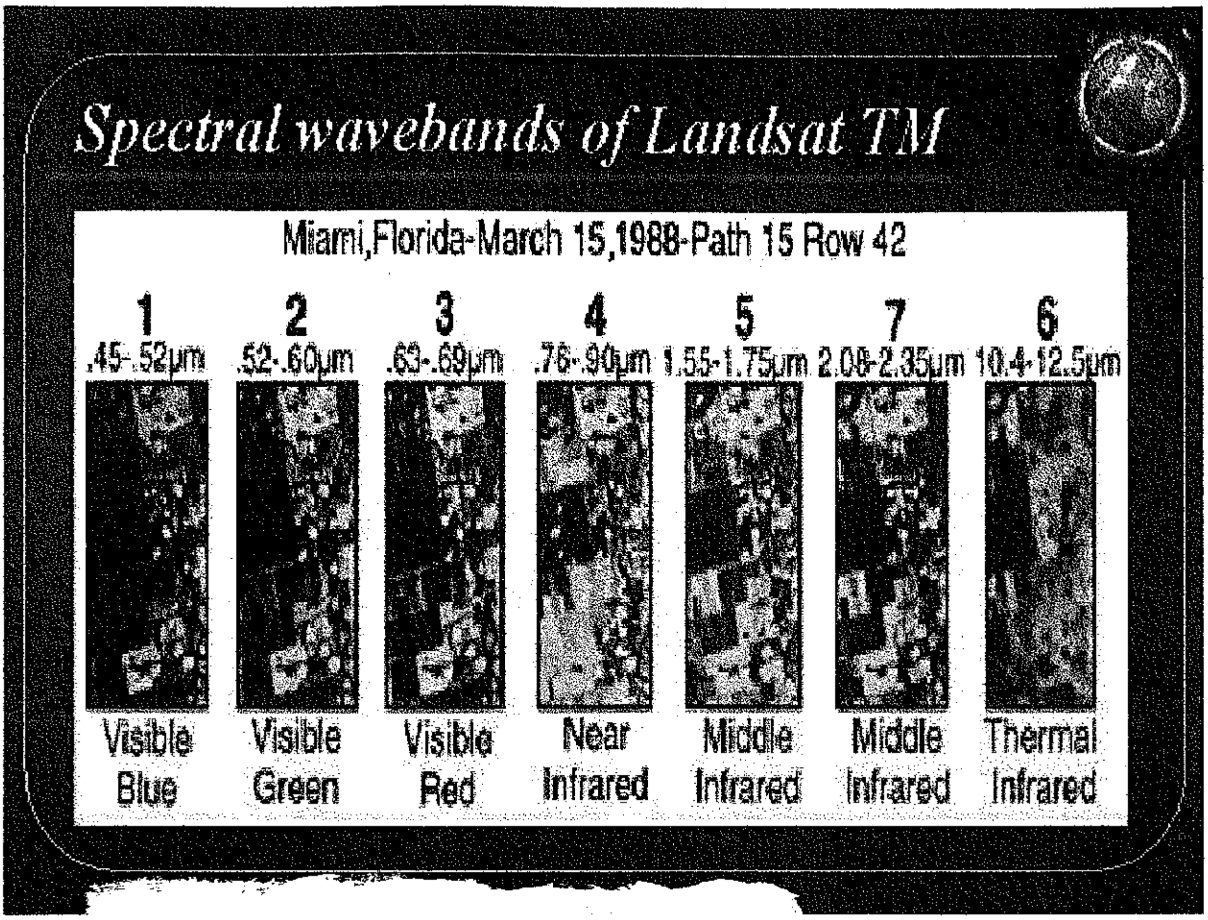
resolution of the imagery, the smaller the region of earth covered in each image. In order to see a large area, such as a county or a state, numerous high-resolution images would be required— an expensive and time-consuming effort. If an organization is working on a regional scale, lower-resolution imagery, which covers a greater area of land, might be a better choice.



The Scale of a Project Usually Determines What Type of Imagery Should Be Used.

Imagery of lower resolution can be used when studying or planning larger regions on the earth, such as a county, state, or even a country. Do not be fooled by the term "lower", it does not mean the imagery is of lesser quality. Rather, the term "lower resolution" means the spatial extent cover by each pixel in the image is large. Thus, this type of imagery can be used for identifying large features such as lakes, forests, and urban areas that cover a substantial amount of the earth's surface.



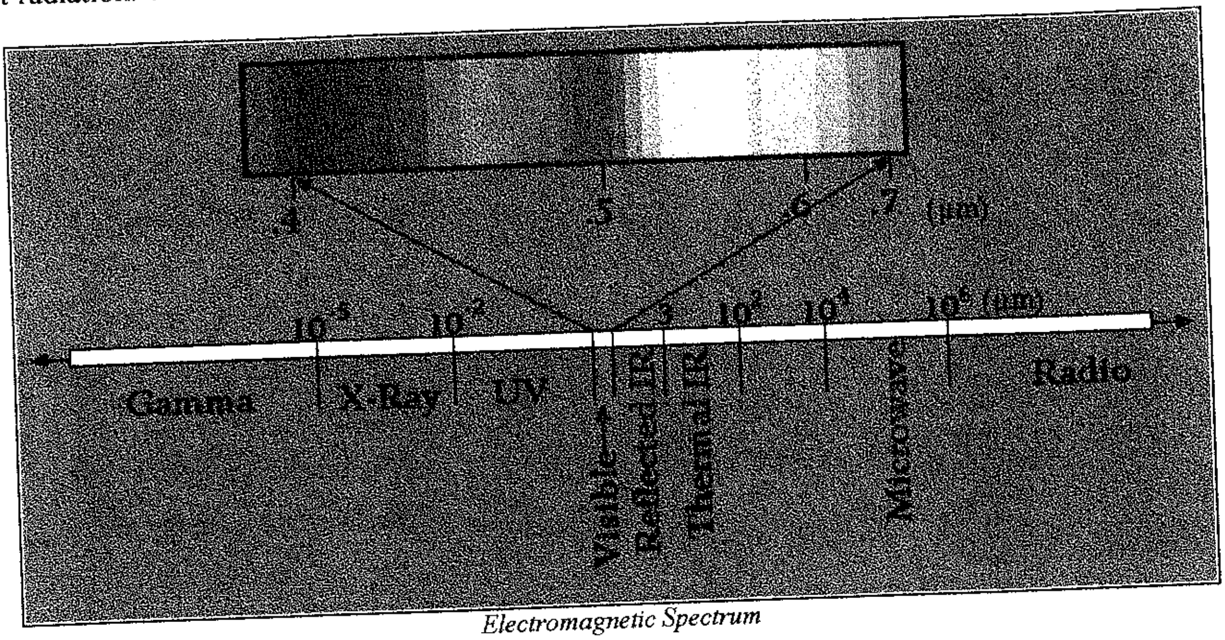

Spectral wavebands of Landsat TM
Miami,Florida-March 15,1988-Path 15 Row 42
1
.45-.52µm
Visible Blue
2
.52-.60µm
Visible Green
3
.63-.69µm
Visible Red
4
.76-.90µm
Near Infrared
5
1.55-1.75µm
Middle Infrared
7
2.08-2.35µm
Middle Infrared
6
10.4-12.5µm
Thermal Infrared

3 (A)

Remote Sensing: The Logistics

How Sensors Work: The Basics

Sensors collect and store data about the spectral reflectance of natural features and objects, both of which reflect radiation. This radiation can be quantified on an electromagnetic spectrum.



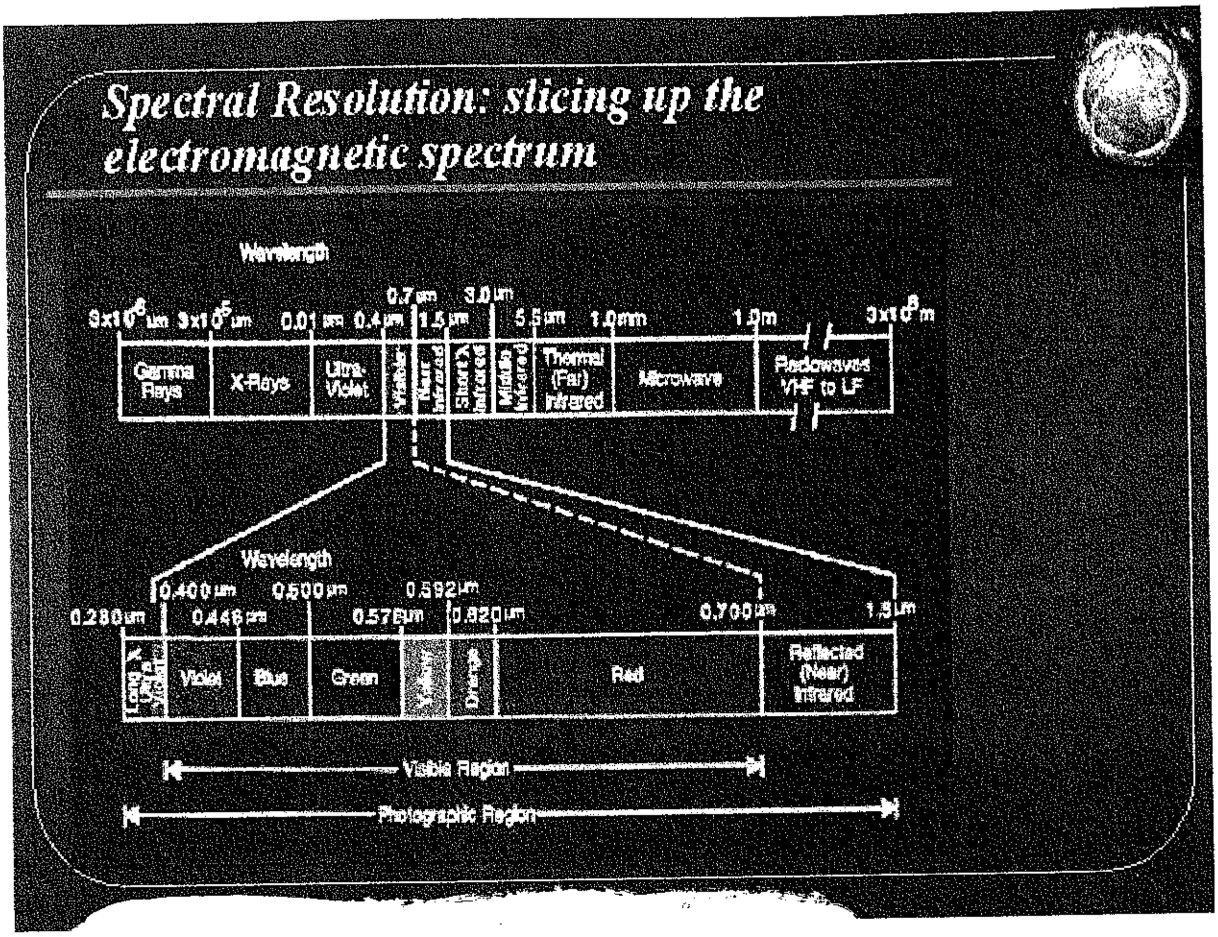
Electromagnetic Spectrum

The electromagnetic spectrum is a continuum of electromagnetic energy arranged according to its frequency and wavelength. As the electromagnetic waves are radiated through space, their energy interacts with matter and one of three reactions occurs. The radiation will either be:

1. reflected off the object
2. absorbed by the object
3. transmitted through the object

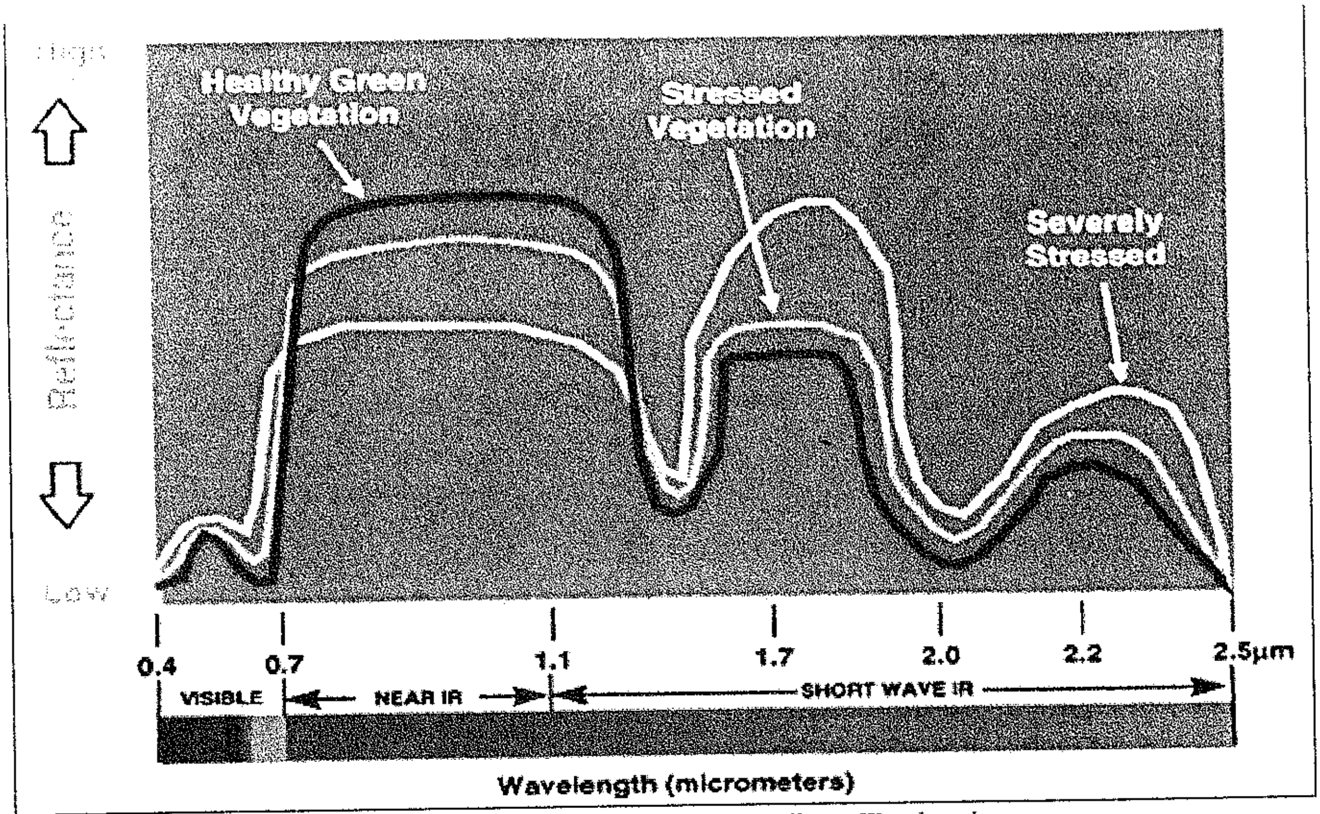
The total amount of radiation that strikes an object is referred to as the incident radiation, and is equal to:

incident radiation = reflected radiation + absorbed radiation + transmitted radiation



Spectral Resolution: slicing up the electromagnetic spectrum
Wavelength
0.7 µm
3.0 µm
0.01 µm
0.4 µm
1.5 µm
5.5 µm
1.0 mm
1.0 m
Gamma Rays
X-Rays
Ultra-Violet
Visible
Near Infrared
Short λ Infrared
Middle Infrared
Thermal (Far) Infrared
Microwave
Radiowaves VHF to LF
Wavelength
0.400 µm
0.500 µm
0.592 µm
0.280 µm
0.446 µm
0.578 µm
0.620 µm
0.700 µm
1.5 µm
Violet
Blue
Green
Yellow
Orange
Red
Reflected (Near) Infrared
Visible Region
Photographic Region

5



Spectral Reflectance of Vegetation Over Different Wavelengths.

Researchers studying terrestrial vegetation most often use sensors that are able to collect data in the near-infrared region of the spectrum. Near-infrared sensors are capable of measuring the chlorophyll contained in plant material. The agricultural community is a frequent user of infrared remote sensing imagery because it can distinguish crop stress before the human eye can detect it. Using infrared imagery to evaluate the stress level of their crops, farmers can make important water and fertilizer application decisions. The illustration below displays an image captured with an infrared sensor.

6

METHOD	EM SPECTRUM	INFORMATION	INTERPRETATION	MISSION
Gamma-Ray Spectroscopy	Gamma rays	Gamma spectrum	K, U, Th Abundances	Apollo 15, 16: Venera
X-ray Fluorescence spectrometry	X-rays	Characteristic Wavelengths	Surface mineral/ chemical comp.	Apollo; Viking Landers
Ultraviolet Spectrometry	UV	Spectrum of Reflected sunlight	Atmospheric Composition: H,He,CO_2	Mariner; Pioneer; voyager
Photometry	UV, Visible	Albedo	Nature of Surface; Composition	Earth Telescopes; Pioneer
Multispectral Imagers	UV, Visible, IR	Spectral and Spatial	Surface Features; Composition	On most missions
Reflectance Spectrometers	Visible, IR	Spectral intensities of reflected solar radiation	Surface Chemistry; mineralogy; processes	Telescopes; Apollo
Laser Altimeter	Visible	Time delay between emitted and reflected pulses	Surface Relief	Apollo 15,16,17
Polarimeter	Visible	Surface Polarization	Surface Texture; Composition	Pioneer; Voyager
Infrared Radiometer (includes scanners)	Infrared	Thermal radiant intensities	Surface and atmospheric temperatures; compos.	Apollo; Mariner; Viking; Voyager
Microwave Radiometer	Microwave	Passive microwave emission	Atmosphere/Surface temperatures; structure	Mariner; Pioneer Venus
Bistatic Radar	Microwave	Surface reflection profiles	Surface Heights; roughness	Apollo 14,15,16; Viking
Imaging Radar	Microwave	Reflections from swath	Topography and roughness	Magellan; Earth systems
Lunar Sounder	Radar	Multifrequency Doppler Shifts	Surface Profiling and imaging; conductivity	Apollo 17
S-Band Transponder	Radio	Doppler shift single frequency	Gravity data	Apollo
Radio Occultation	Radio	Frequency and intensity change	Atmospheric density and pressure	Flybys and Orbiters

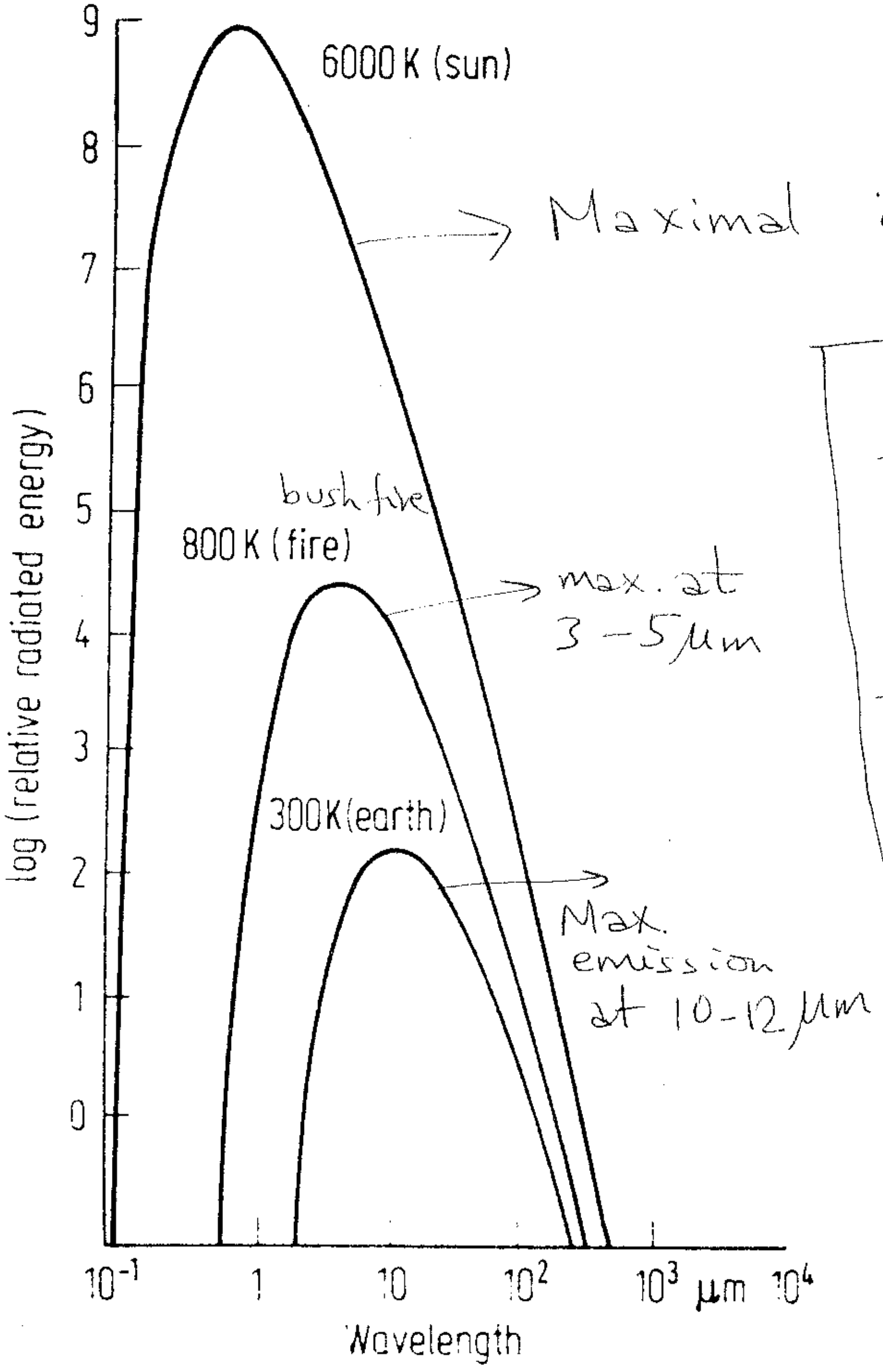
7

Landsat TM: each waveband provides different information about earth surface features

Band	Wavelength	Description	Characteristics and Notes
1	.45-.52	Visible Blue	Maximum water penetration; vegetation vs soil; deciduos vs. conifers
2	.52-.60	Visible Green	Plant vigor (reflectance peak for plants)
3	.63-.69	Visible Red	Chloropyll absorption; vegetation discrimination
4	.76-.90	Near Infrared	Reflected IR, biomass and shoreline mapping
5	1.55-1.75	Middle Infrared	Reflected IR; moisture content of soil and vegetation; cloud/smoke penetration; vegetation mapping
7	2.08-2.35	Middle Infrared	Reflected IR; mineral mapping
6	10.4-12.5	Thermal Infrared	Thermal IR; soil moisture; thermal mapping

8

Black body radiation

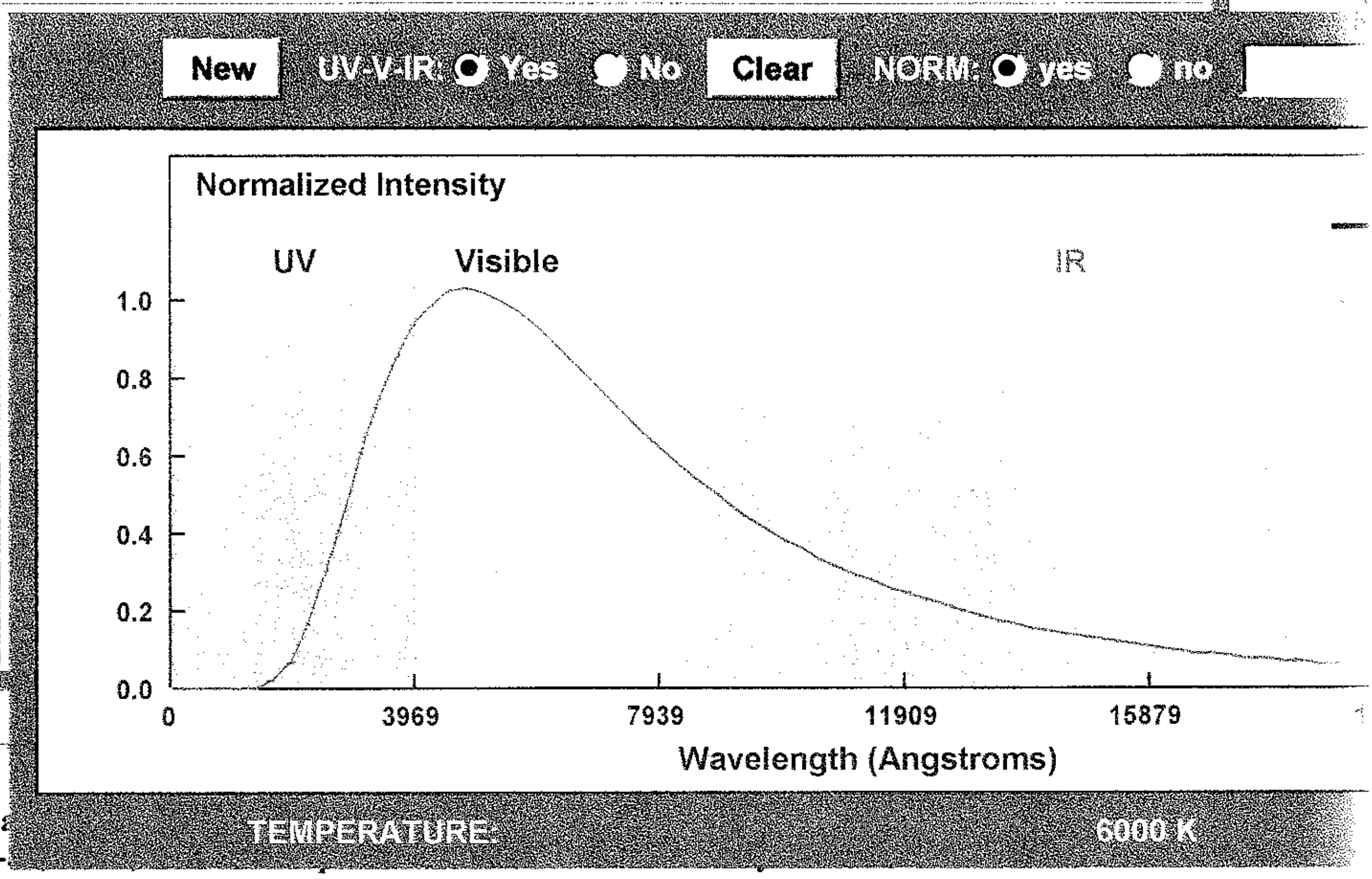


- Curves are in the vicinity of the sources
- From sun to earth, radiative energy $\propto \frac{1}{r^2}$

r = distance from sun to earth

Energy from perfect radiators (**black** bodies) as a function of wavelength

Planck Law Radiation Distributions

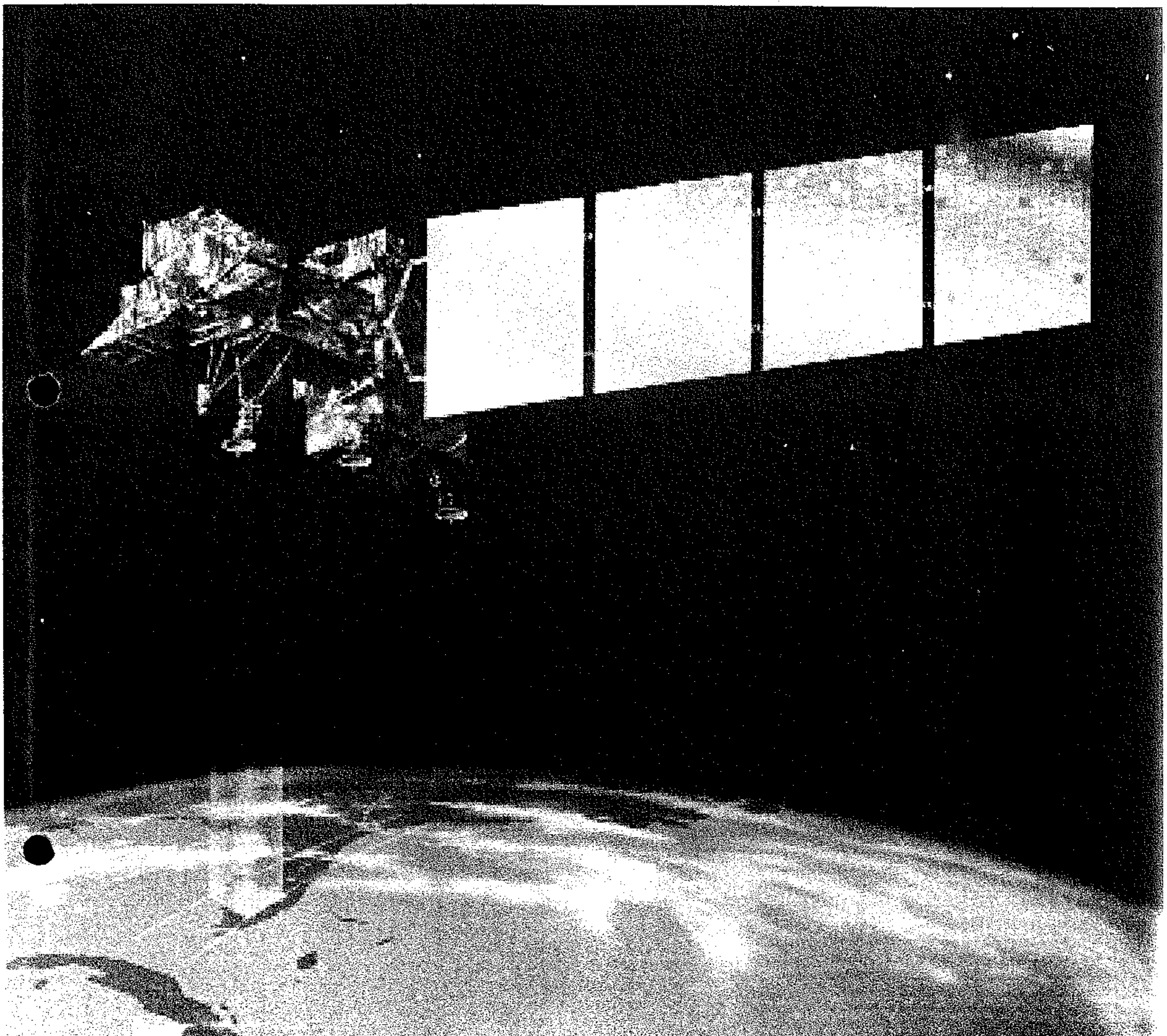


This
3000-
bottom: slide the bar to the temperature desired and click "New" for each case to be plotted. There are three scales of slidebar movement: large moves by dragging the selector, medium (10 or 100 degrees) by clicking in the space between the selector and the right or left end, and 1 degree at a time by clicking the right and left arrows on the slidebar.

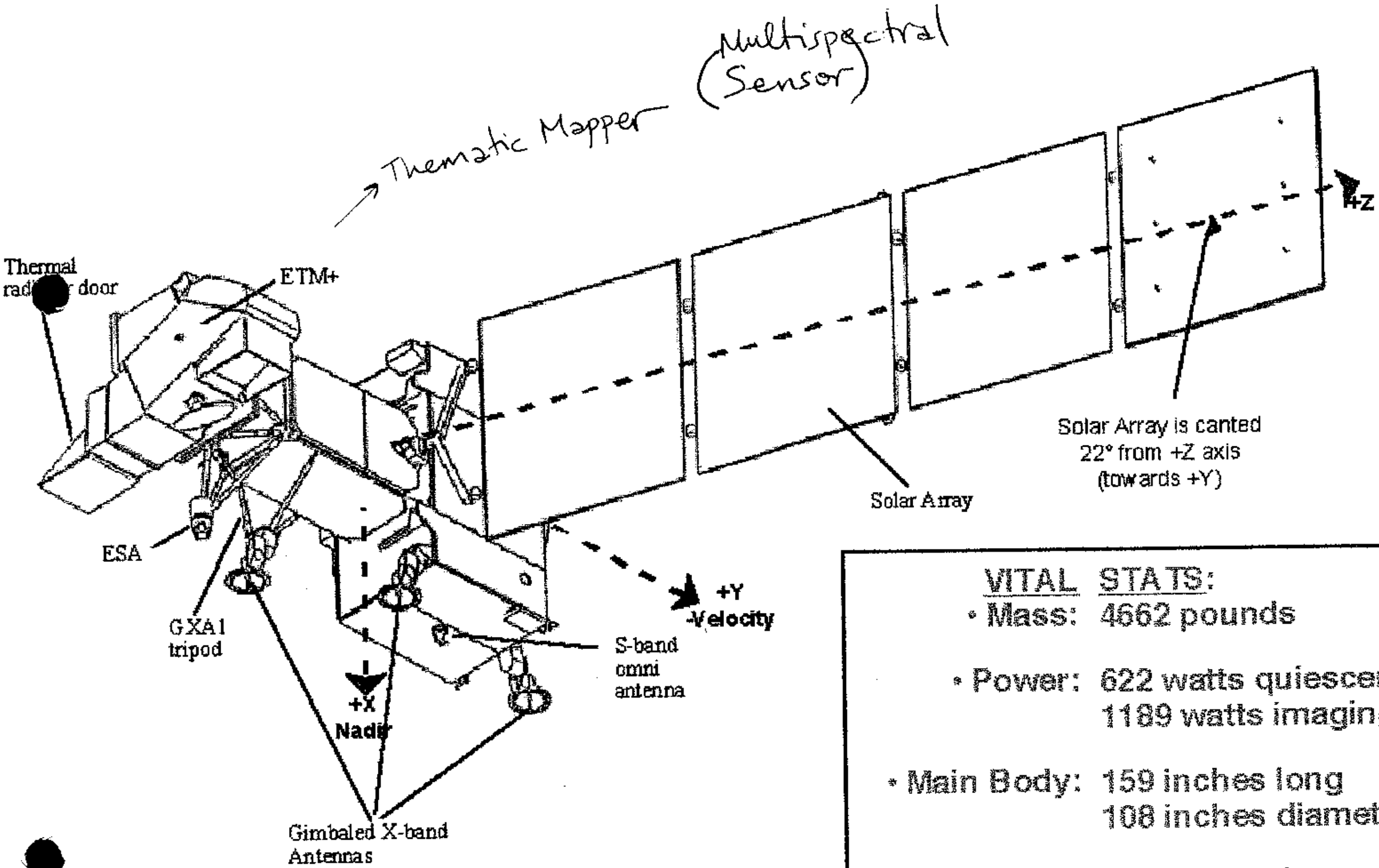
You may choose linear, log, and log-log plot modes using the choice menu at the upper right. For the linear plots you may choose whether to normalize all curves to unit height, or let the curves have their correct relative heights by toggling the Norm checkboxes. You may also choose whether to indicate the UV, visible, and IR ranges of wavelengths explicitly by toggling the UV-V-IR checkboxes. The "Clear" button clears all plots.

Related applets:

9.2



LANDSAT 7



VITAL	STATS:
• Mass:	4662 pounds
• Power:	622 watts quiescent 1189 watts imaging
• Main Body:	159 inches long 108 inches diameter
• Solar Array:	89 x 296 inches

Landsat 7 Drawing

10A

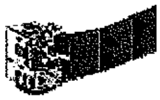
ADDITIONAL PAGE 11

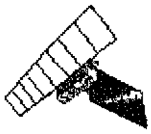

RADARSAT


LANDSAT

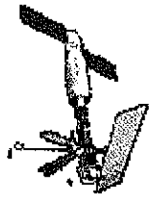

SPOT

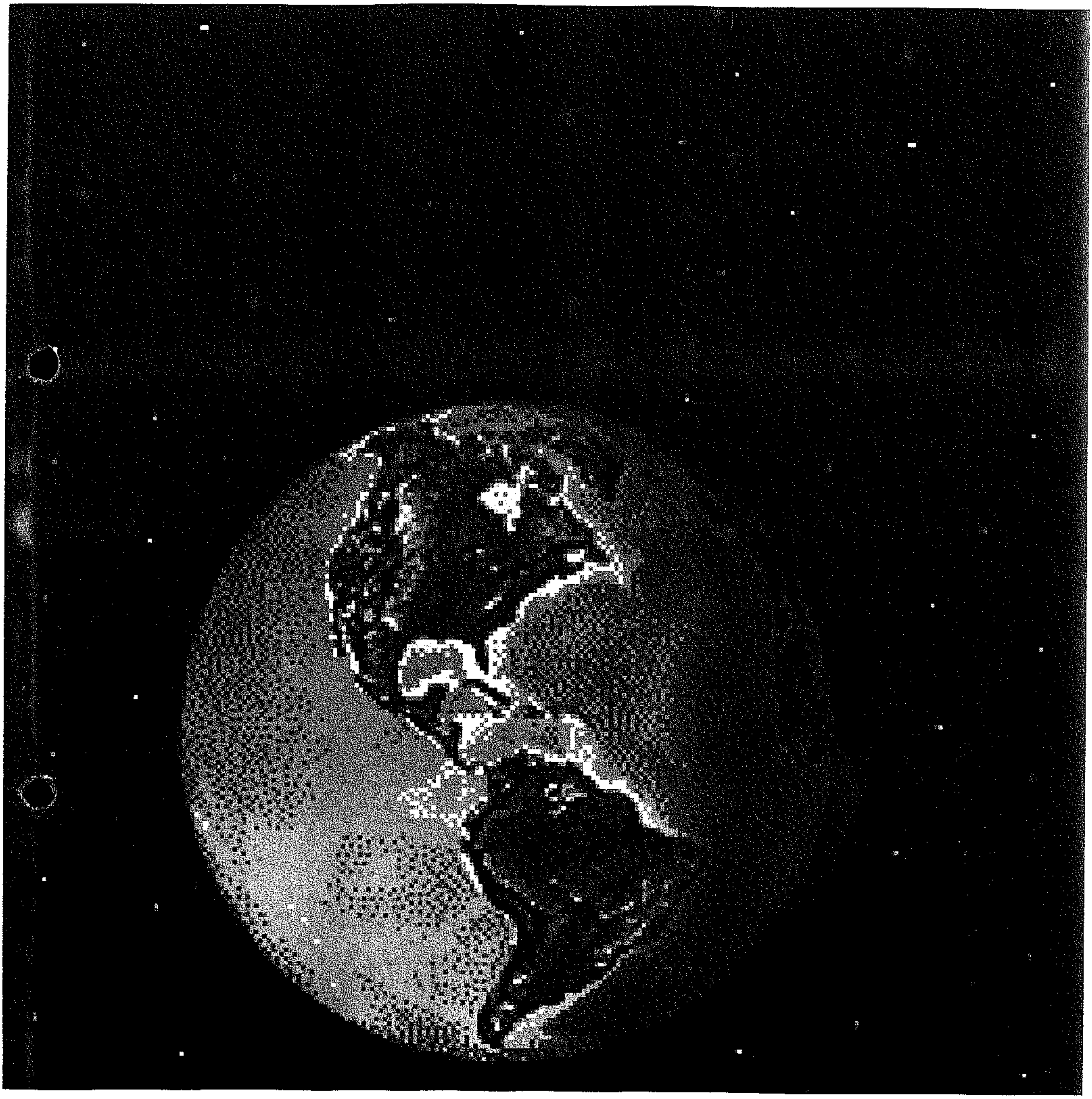

ERS


MOS

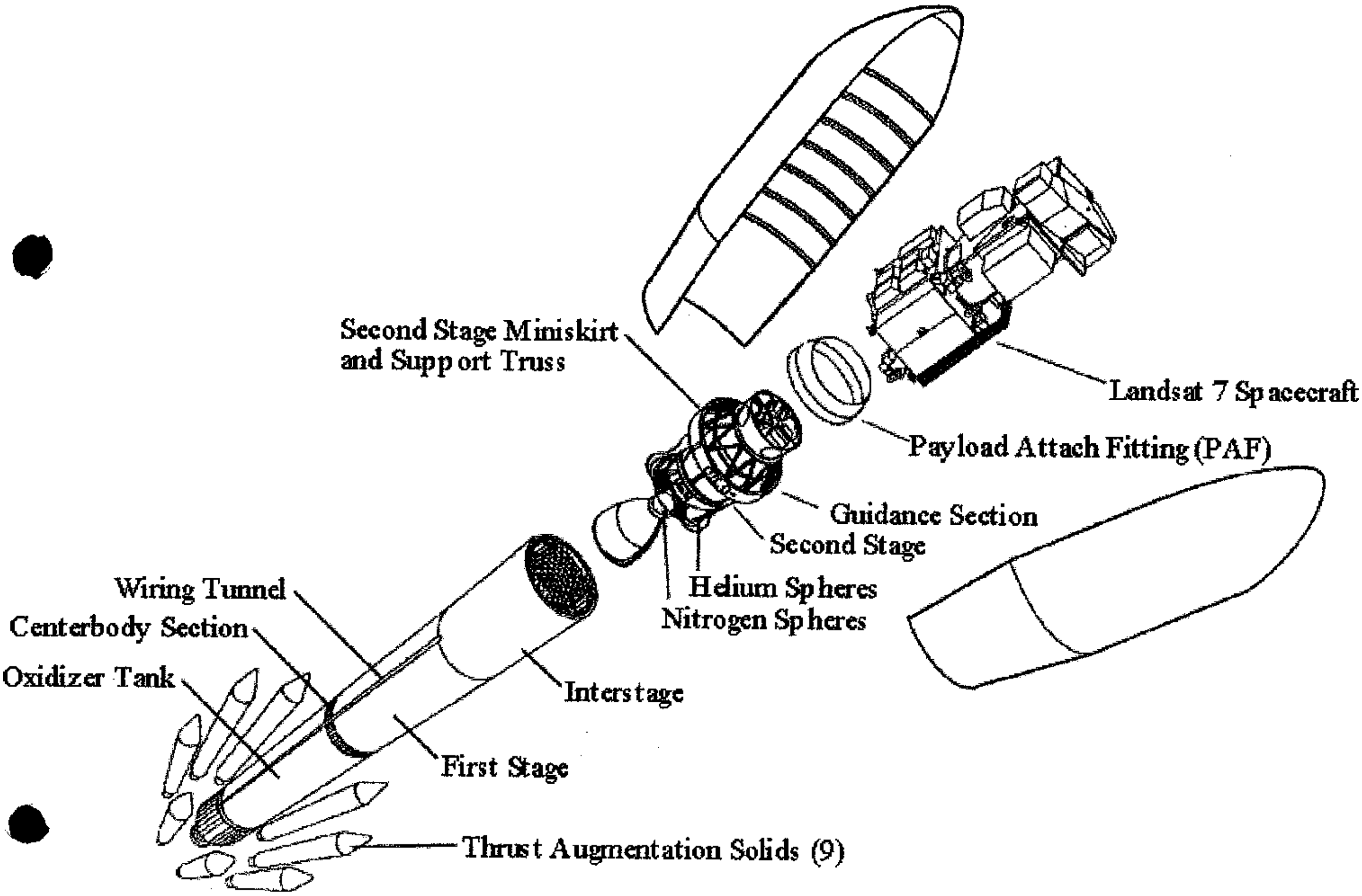

JERS


NOAA


SEASAT



12



satellite Launch Vehicle Drawing

Delta II

For Landsat 7

(13)

Remote sensing satellites

Chronology

1972
(058) Landsat 1

1975
(004) Landsat 2
(070) Dong Fang Hong 03
(110) Dong Fang Hong 04
(119) Dong Fang Hong 05

1976
(087) Dong Fang Hong 06
(117) Dong Fang Hong 07

1977
Meteor 1-28

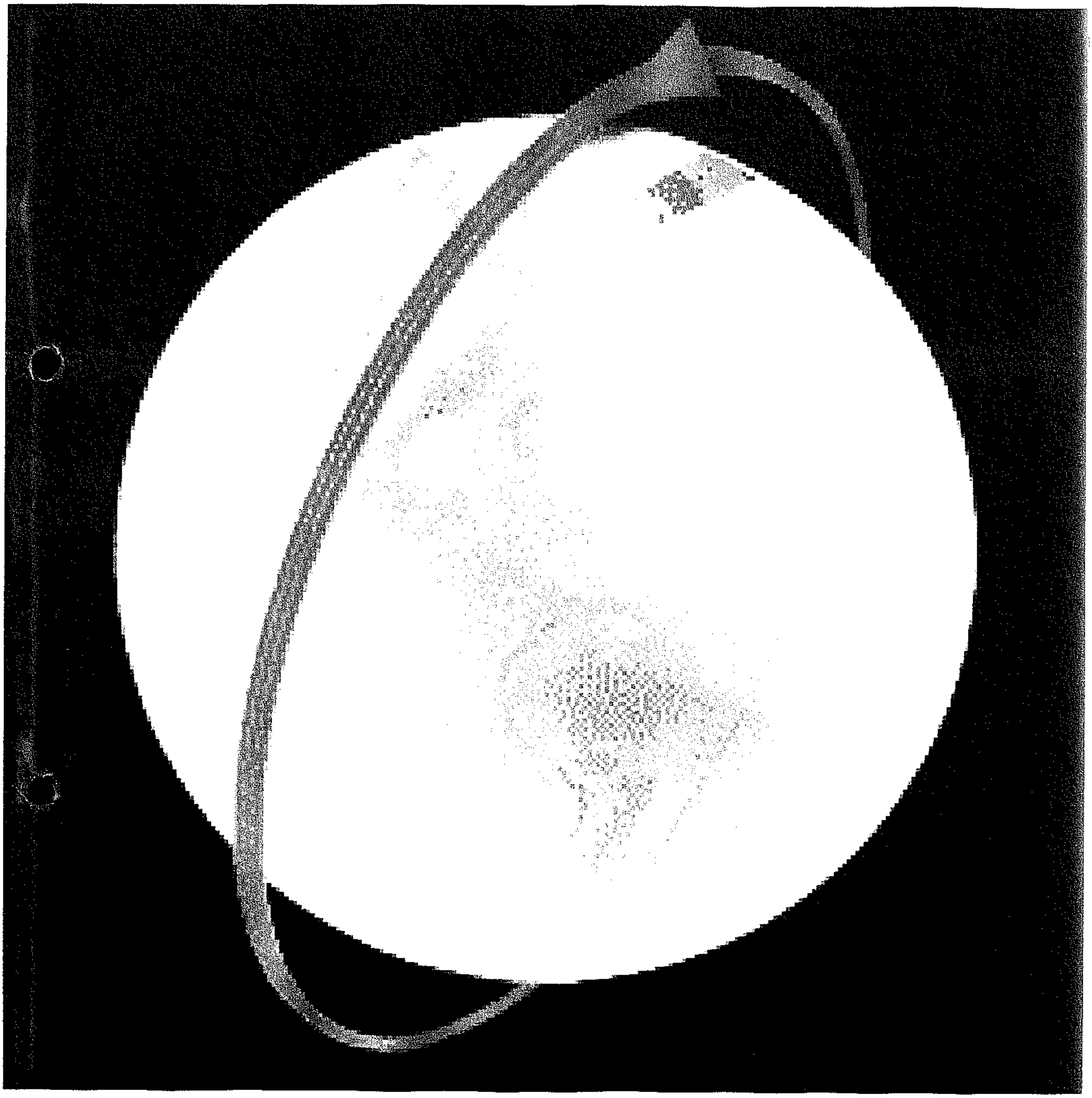
1978
(011) Dong Fang Hong 08
(026) Landsat 3
(041) AEM 1
(064) Seasat
(098) Nimbus 7

1979
Meteor 1-29
Cosmos 1076 (Ocean-E)
(051) Bhaskara 1
Intercosmos 20

1980
Cosmos 1151 (Ocean-E)
Meteor 1-30

1981

(14)

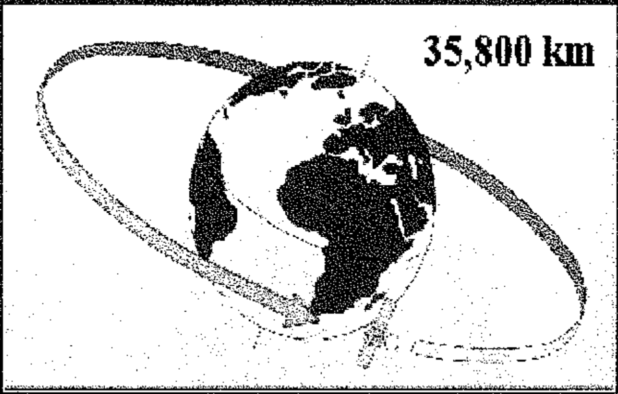


Near
Polar
orbit

Satellite remote sensing orbits give repeat coverage

- Geostationary
- Constant view of hemisphere

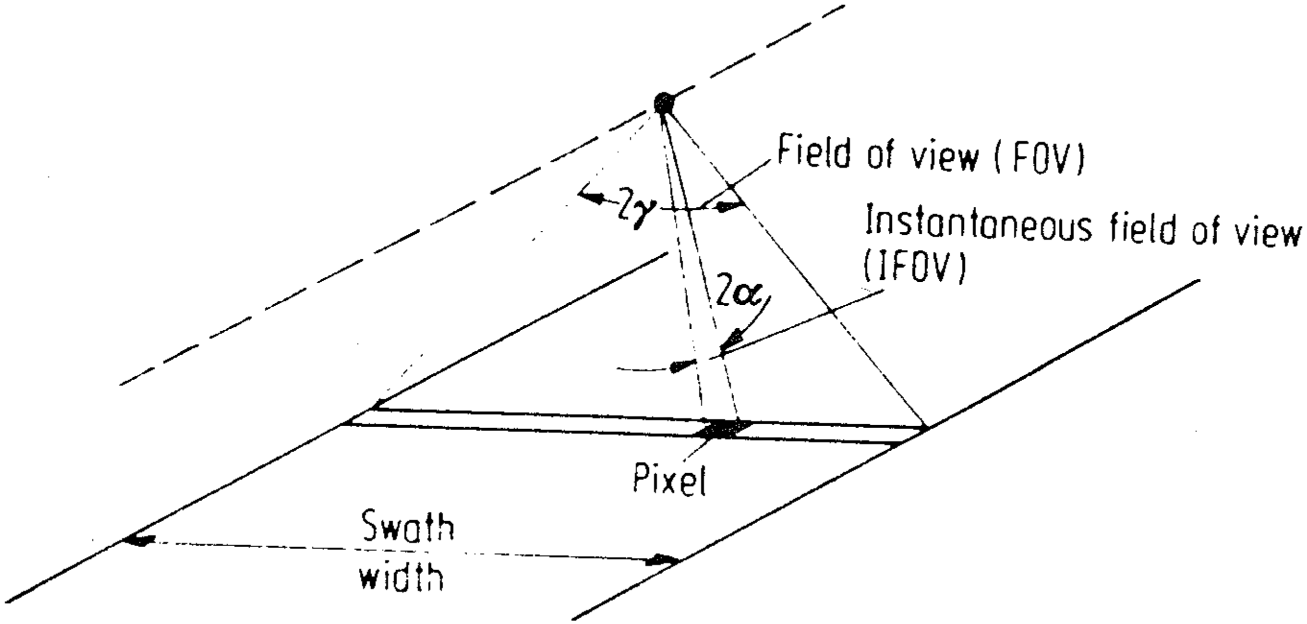
Polar Sun-synchronous
Covers entire Earth

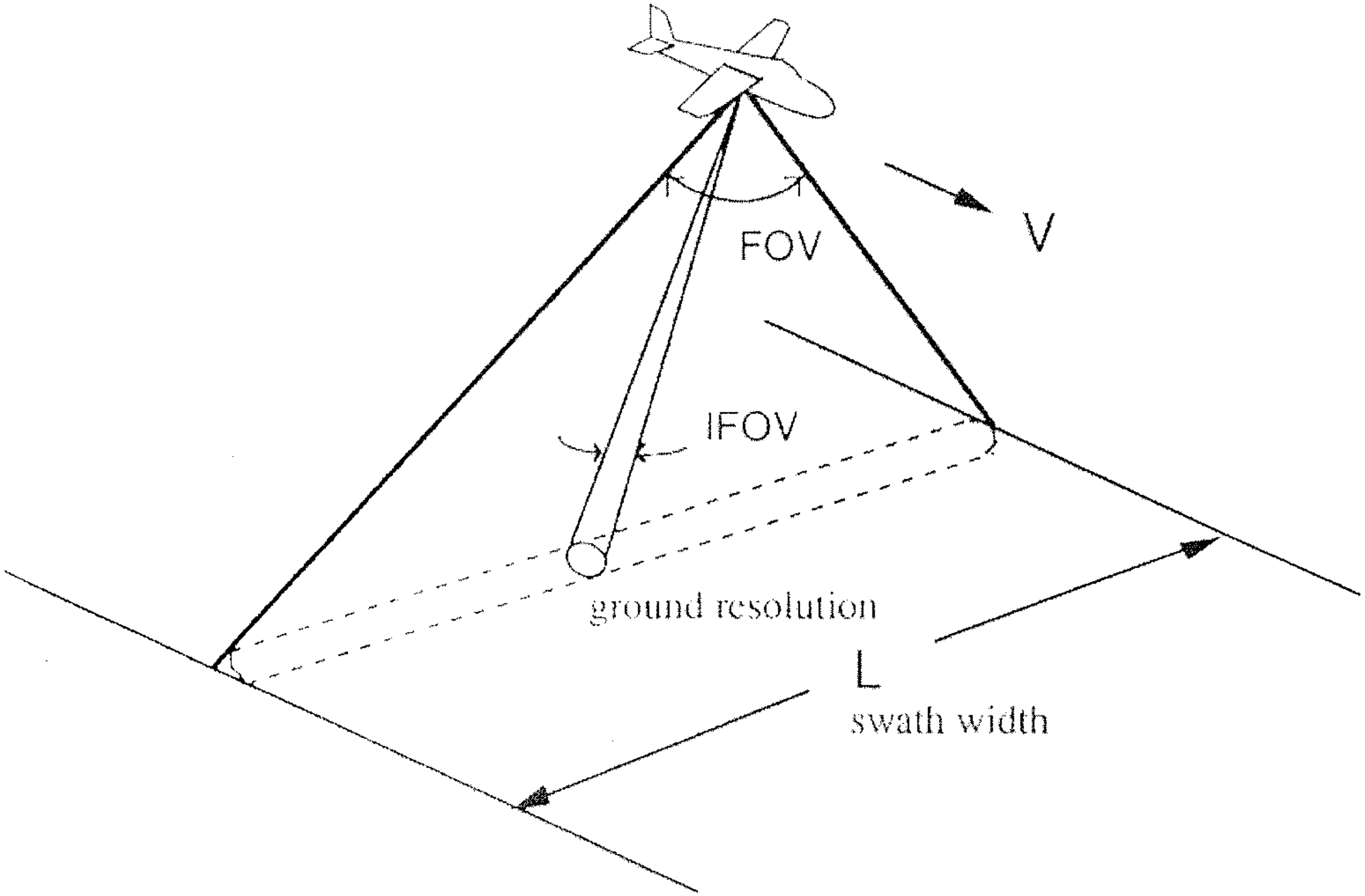


← Polar Orbi

Geostationary

16


Field of view (FOV)
Instantaneous field of view
(IFOV)
2γ
2α
Pixel
Swath
width

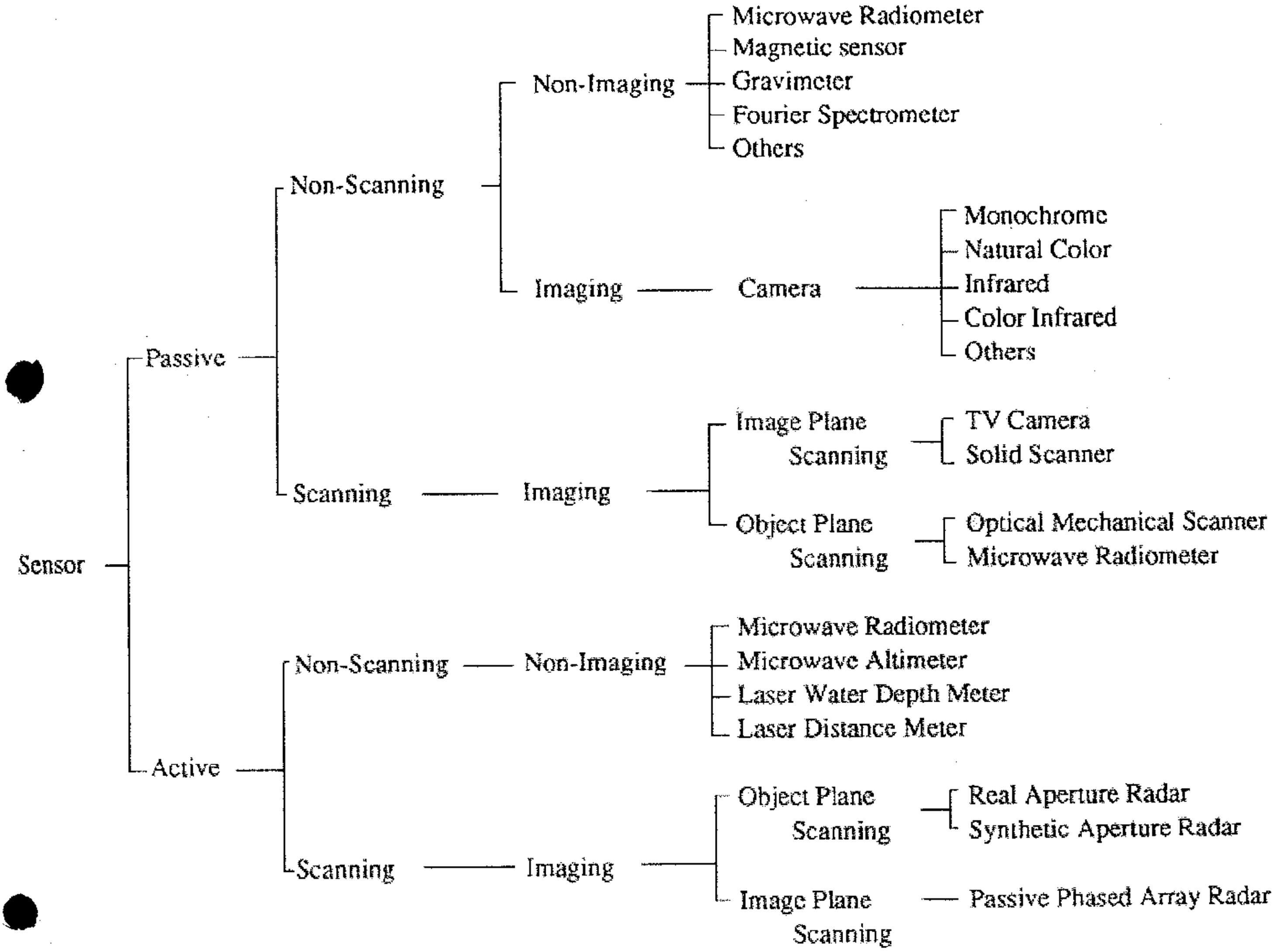


FOV and IFOV

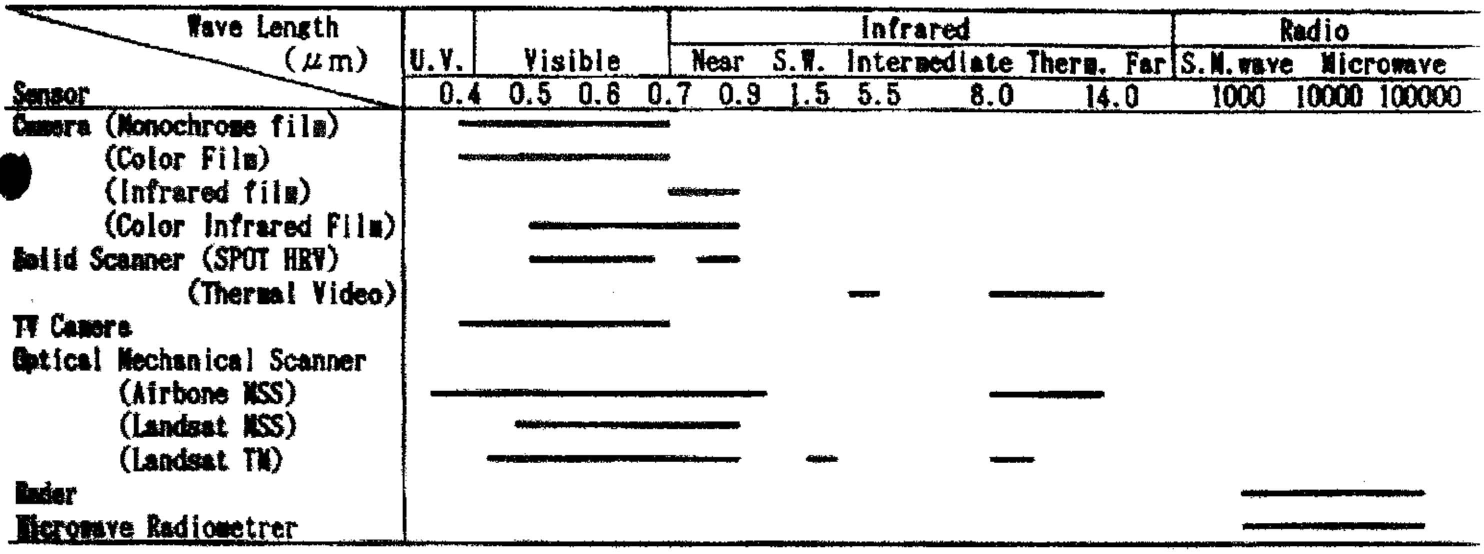
18

Satellites	Sensors	*Optical*	*Radar*	*Spatial resolution* >2KM	2KM-100M	100M-10M
ADEOS	TOMS	X		X		
CORONA		X				
COSMOS	TK-350	X				X
	KVR-1000					
EARTH PROBE	TOMS	X		X		
ENVISAT		X	X		X	X
ERS	AMI-SAR		X			
	ATSR		X	X		X
	GOME	X		X		
IKONOS		X				
IRS-1C	PAN	X				
	LISS-III	X				X
	WIFS	X			X	
JERS	SAR		X	X		X
	OPS	X				X
LANDSAT	TM	X				X
	RBV	X				X
	ETM+	X				X
	MSS	X				X
METEOR 3	TOMS	X		X		
METEOSAT	MSR	X		X		
NIMBUS 7	TOMS	X		X		
NOAA	AVHRR	X			X	
ORBVIEW2	SEAWIFS	X			X	
QUICKBIRD		X				
RADARSAT	SAR		X			X
RESURS-F	KFA-1000	X				
RESURS 01	MSU-SK	X			X	
SPOT	HRV	X				X
	HRVIR	X				X
	VGT	X			X	
SRTM			X			X

19



Classification of Sensor



Wave Length Band of Principal Sensor

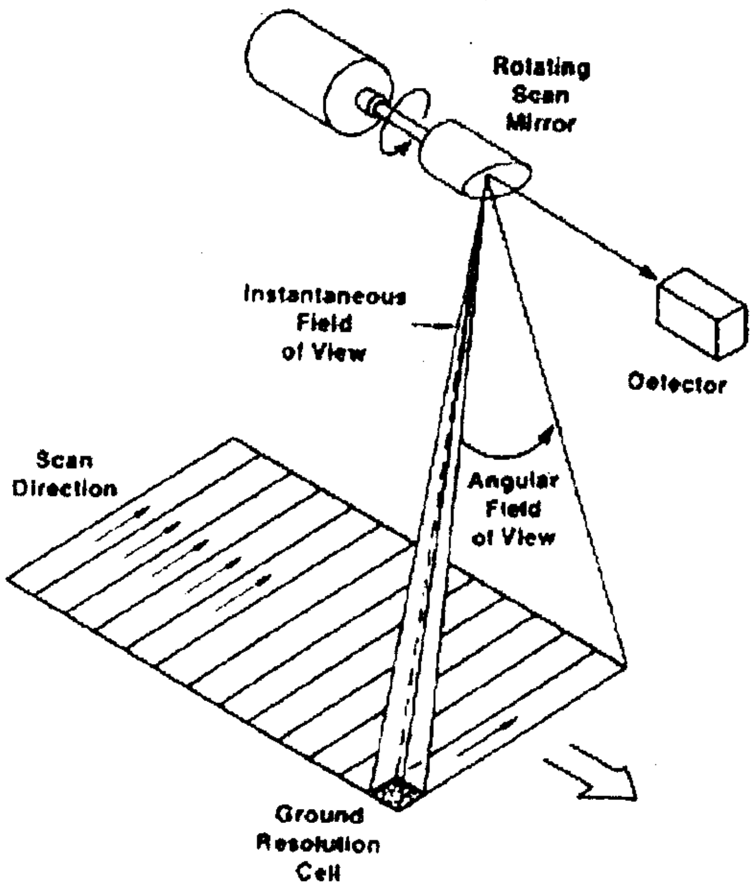
- Sensor
  - Spectral characteristics
    - observation range of EMW
    - changes at both ends of a band
    - sensitivity on out of a band
    - polarization sensitivity
    - sensitivity different between different bands
    - ⋮
  - Radiometric characteristics
    - detecting accuracy
    - signal to noise ratio
    - dynamic range
    - quantization level
    - sensitivity difference between pixels
    - linearity of sensitivity
    - noise equivalent power
    - ⋮
  - Geometric characteristics
    - field of view
    - instantaneous field of view
    - registration between different spectral bands
    - alignments
    - MTF
    - optical distortion
    - ⋮

Elements of optical sensors characteristics

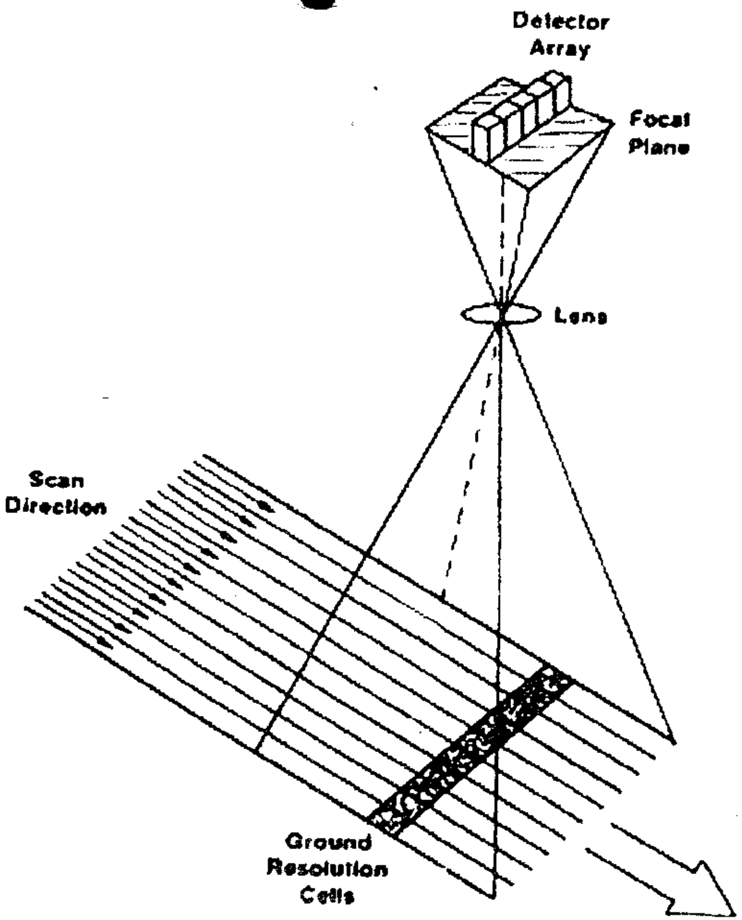
(Two pages) ⇒

Definition of optical sensor's characteristics

items	definition
band range of EMW	observation width of EMW(Electro magnetic waves) on a band
center wavelength	center wave length on a band
band responsibility at both ends of a band	characteristics curve at both ends of a band
band sensitivity	sensitivity on a band
without band sensitivity	sensitivity on spectral ranges of outside of the band
sensitivity difference between different bands	ratio of sensitivity between different bands
S/N ratio	signal to noise ratio
dynamic range	range of sensor's sensitivity in terms of the difference maximum and minimum radiance ratio
sensitivity difference between pixels	ratio of maximum output level to minimum output levels pixels
linearity of sensor's input-output characteristics	input level to output level in higher input power level
noise equivalent power	input signal power giving output equivalent with noise power
field of view	covered area by a remote sensor, picture (angular field of camera, scanning width by scanner
instantaneous field of view (IFOV)	field of angle detected by one detector
registration between different spectral bands	geometric distortion between one standard band and other bands
MTF	modulation transfer function of a sensor, determining it's IFOV
optical distortion	image distortion due to optical components of a sensor. e.g. lens aberration
angle of stereoscopic observation	difference of viewing angle of stereoscopic sensors
imaging frequency	time of scanning one line

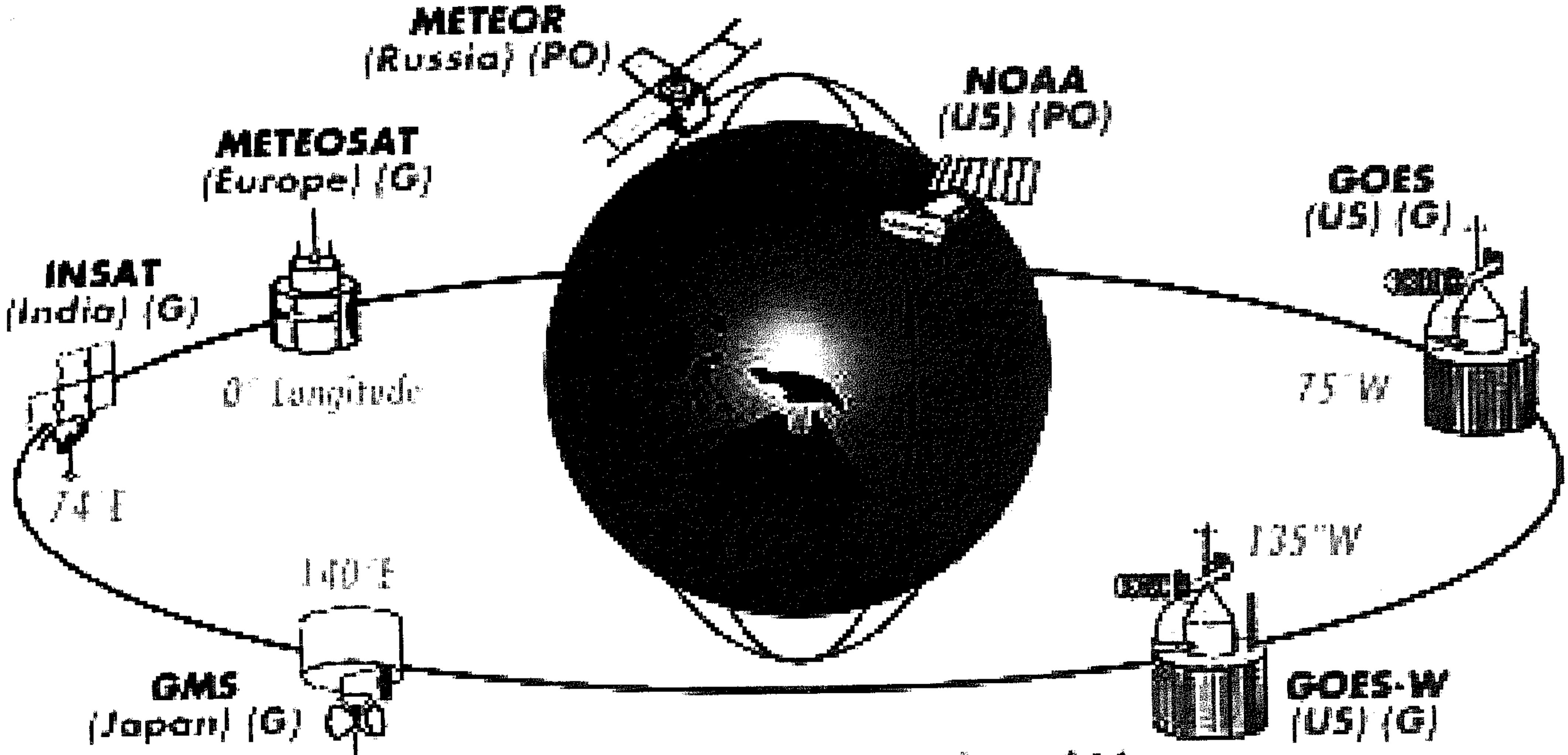


A. CROSS–TRACK SCANNER.



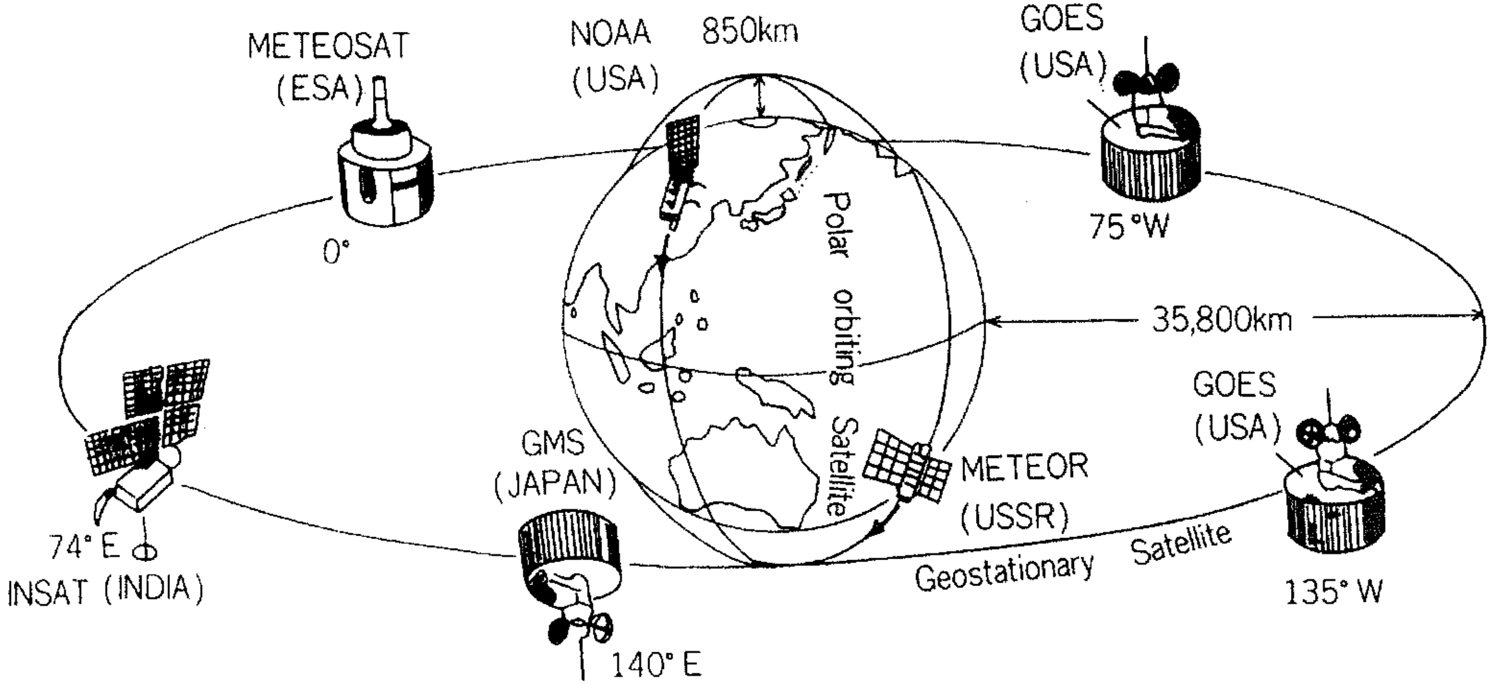
C. ALONG–TRACK SCANNER.

Weather (Geostationary)



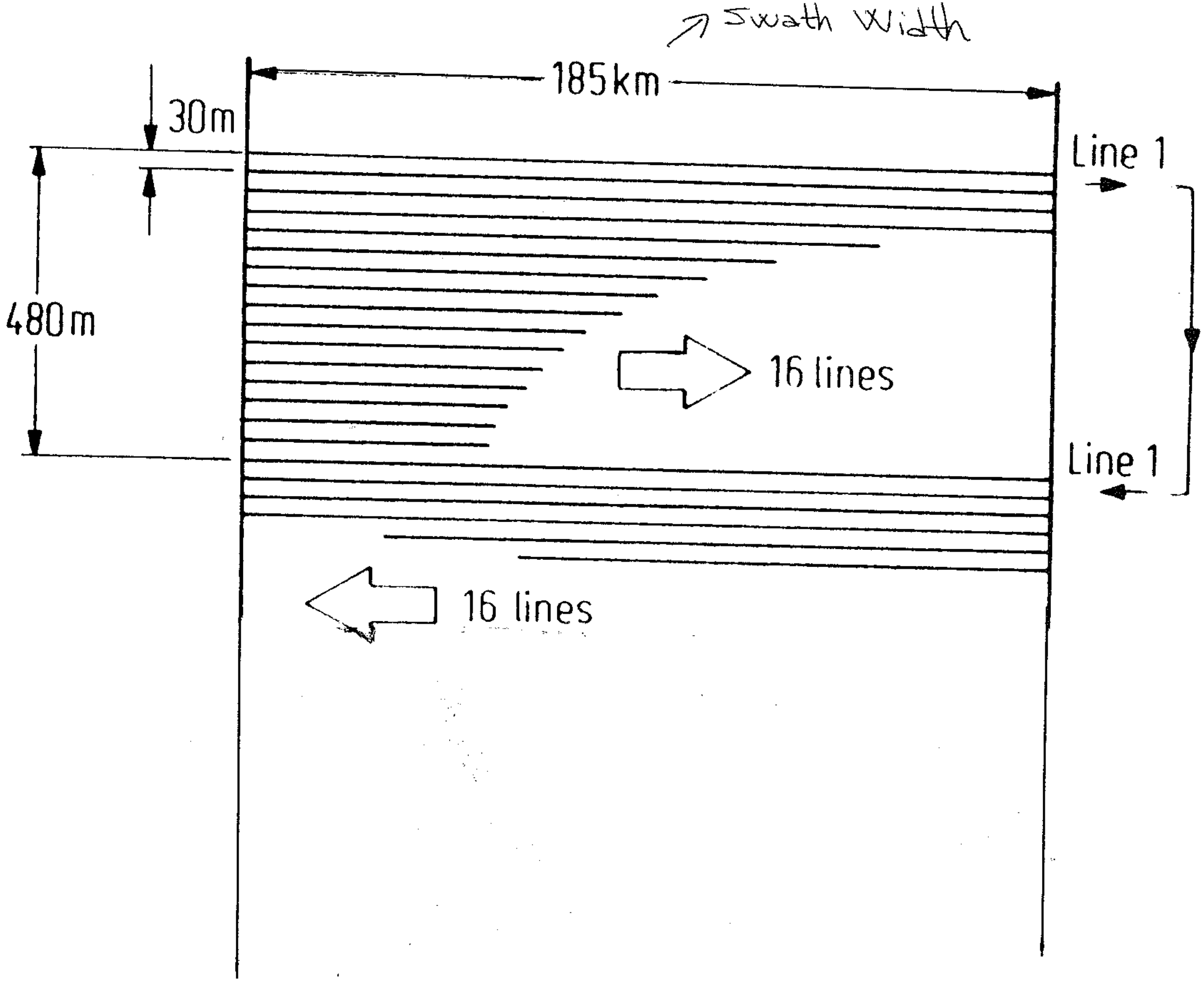
G = Geostationary   PO = Polar orbiting

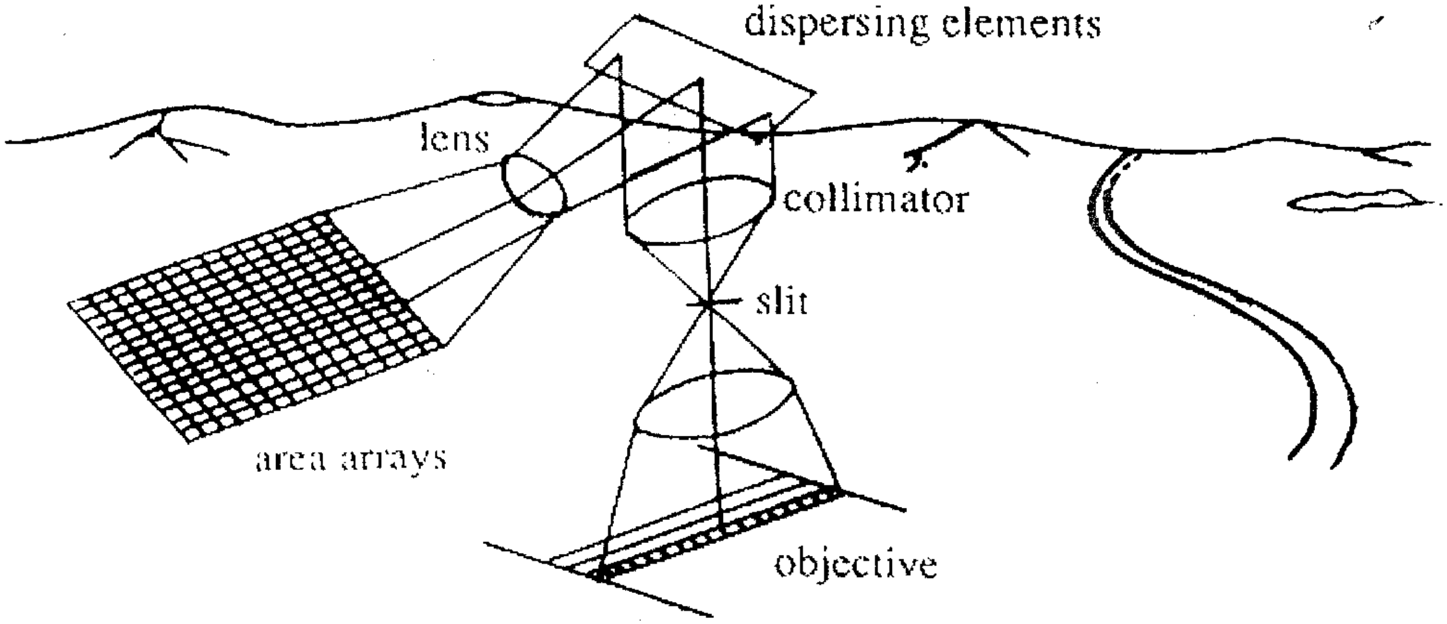
Weather
(Geostationary)



Location of geostationary satellite

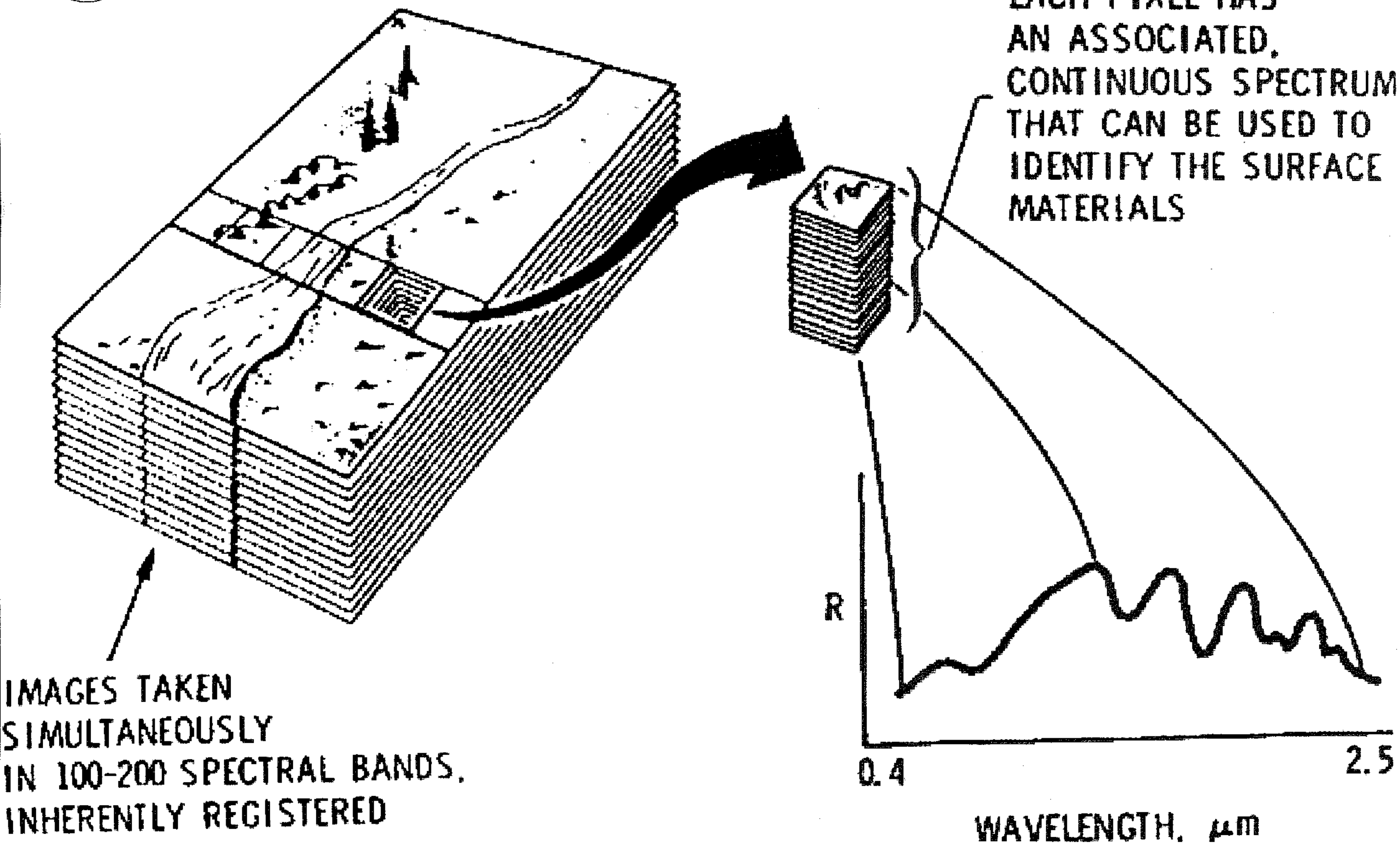
SCANNING CHARACTERISTICS OF THE LANDSAT THEMATIC MAPPER (TM)



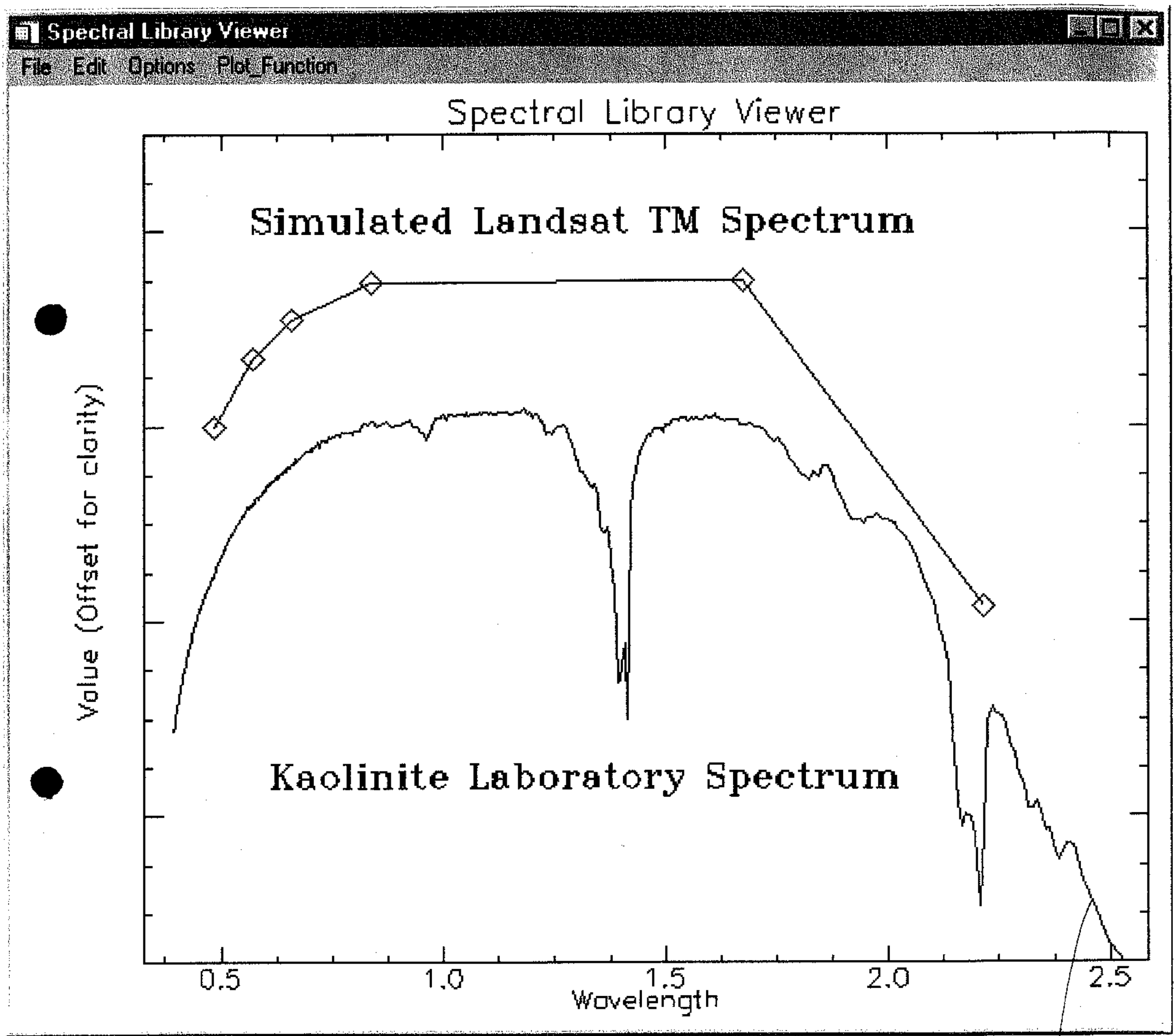


Imaging spectrometry with area array

27



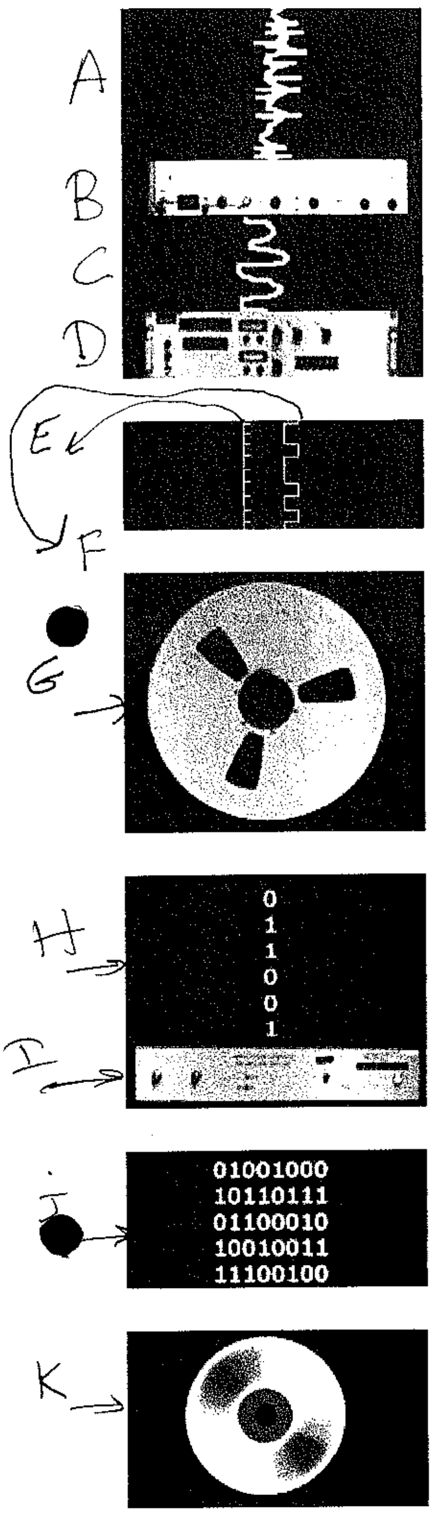
IMAGES TAKEN
SIMULTANEOUSLY
IN 100-200 SPECTRAL BANDS,
INHERENTLY REGISTERED
EACH PIXEL HAS
AN ASSOCIATED,
CONTINUOUS SPECTRUM
THAT CAN BE USED TO
IDENTIFY THE SURFACE
MATERIALS
R
0.4
2.5
WAVELENGTH, µm



Comparison of
TM (6 bands in TM)
Imaging Spectrometer (100's of bands)

Imaging Spectrometer

Data Stream Handling



Original to intermediate frequency

The original X-band data at approximately 8GHz are received and converted by the "downconverters", located within the antenna structure, to an intermediate frequency of 375 MHz.

Intermediate to 'raw' digital data

The intermediate data stream are then converted into two different data streams (comprised of data and clock synchronization) by a "bit-synchronizer" housed within the station building computer facility. The resulting information is stored on special digital recording systems.

Computer-readable data

The digital data stream from a digital recording system is passed through a "frame synchronizer", which prepares the data in "image" form. The data is now fully compatible for conventional computer

A = Original X-Band Data From Satellite Reaching Earth Station (8 GHz)

B = Downconverter

C = IF = Intermediate Frequency (375 MHz)

D = Conversion to Data Stream

E = Clock Synchronizer Signal

F = Data

G = Digital Recording System

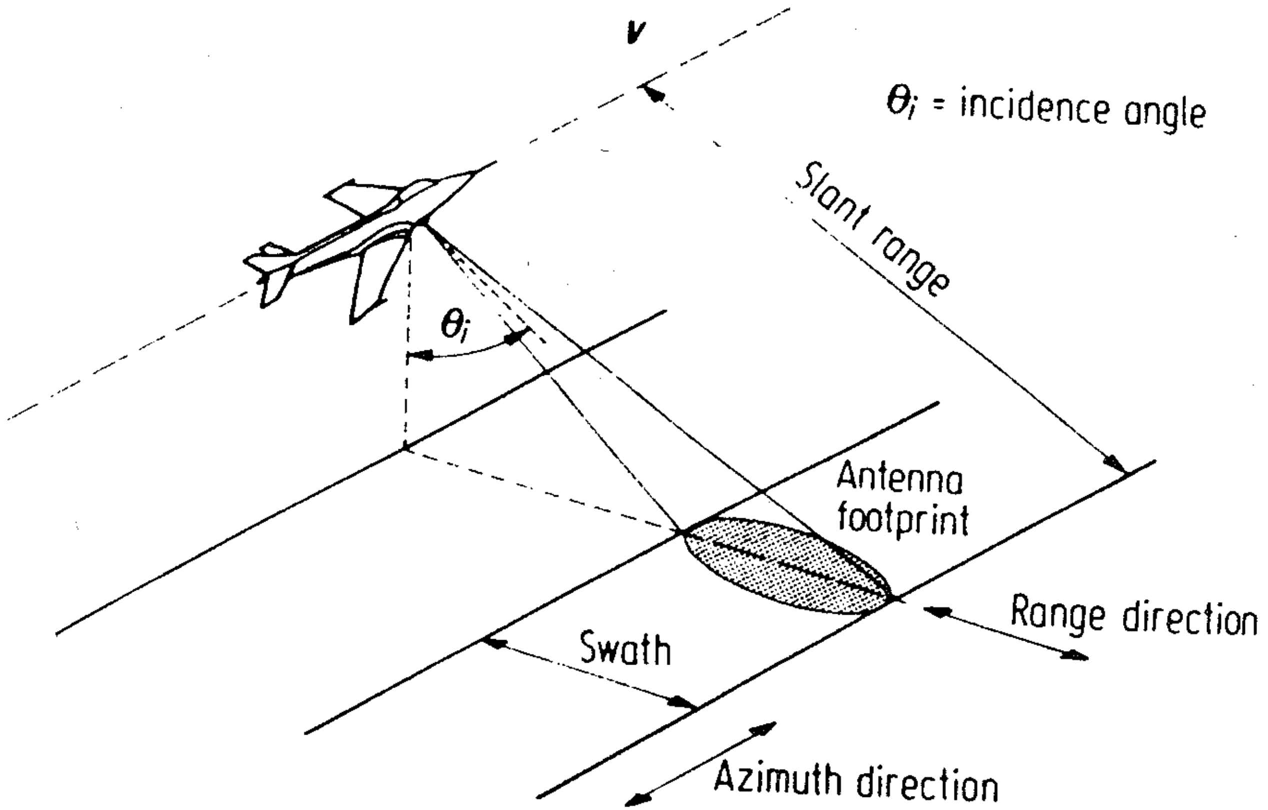
H = Digital Data Stream

I = Frame Synchronizer

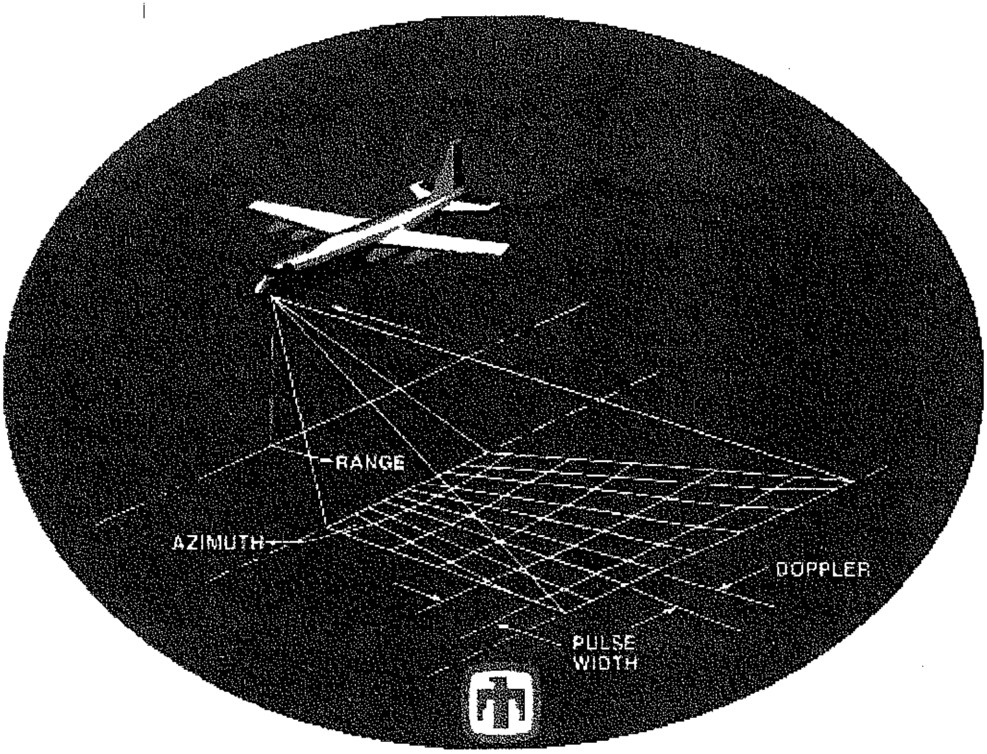
J = Data in Image Form

K = Computer Storage (Tape or CD)

29

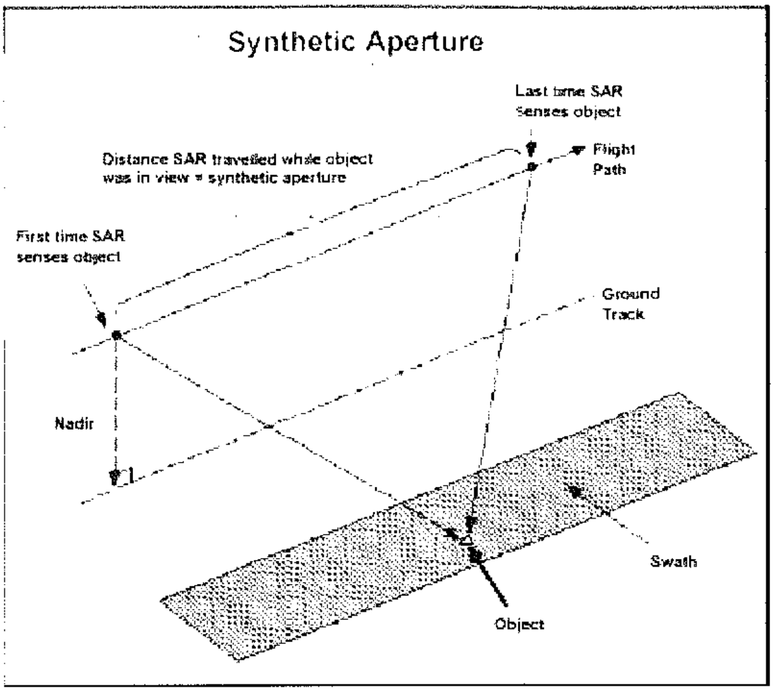


Principle of side looking radar

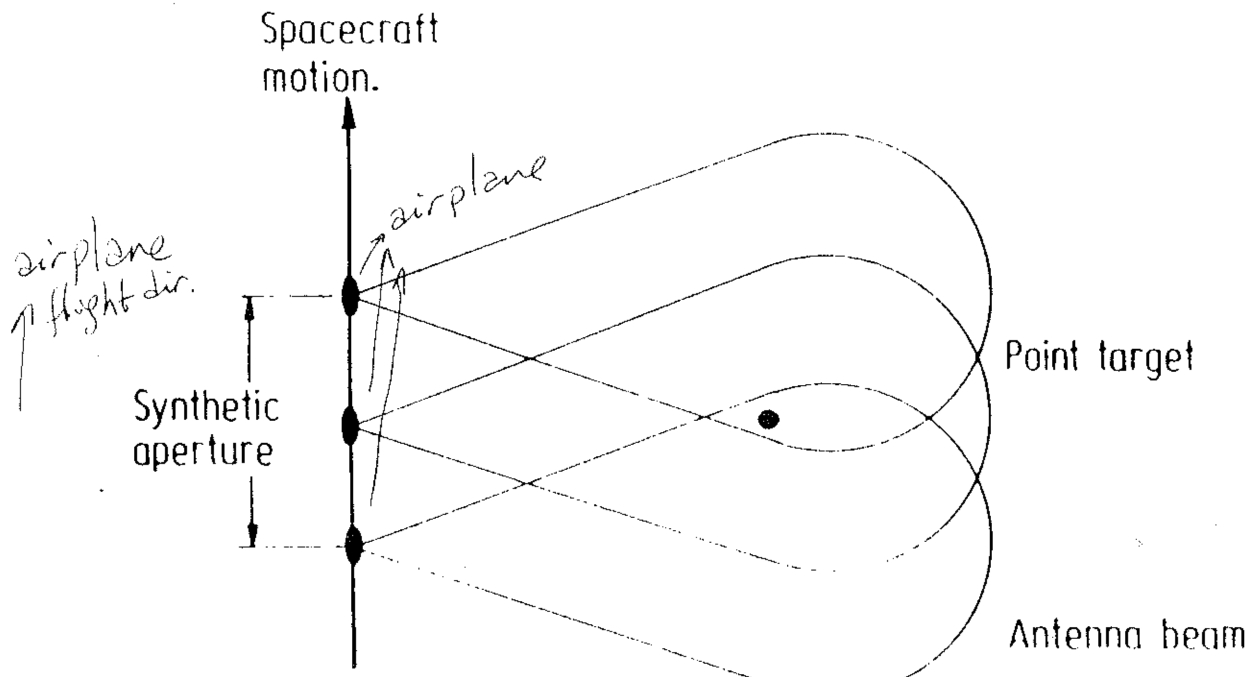


30

Concept of Synthetic Aperture



31



The concept of synthesizing a large antenna by utilizing spacecraft motion along its orbital path. Here a view from above is shown, illustrating that a small real antenna is used to ensure a large real beamwidth in azimuth. As a consequence a point on the ground is illuminated

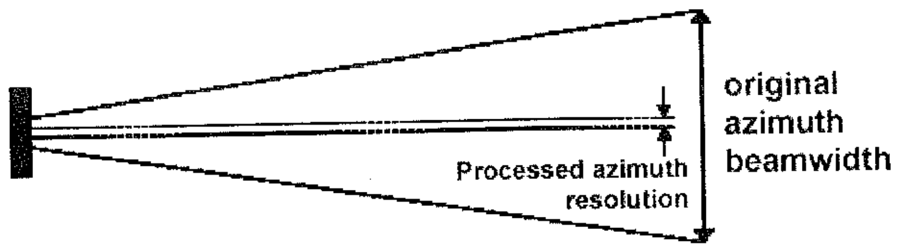
Synthetic Aperture Radar (SAR)

31

Azimuth Resolution

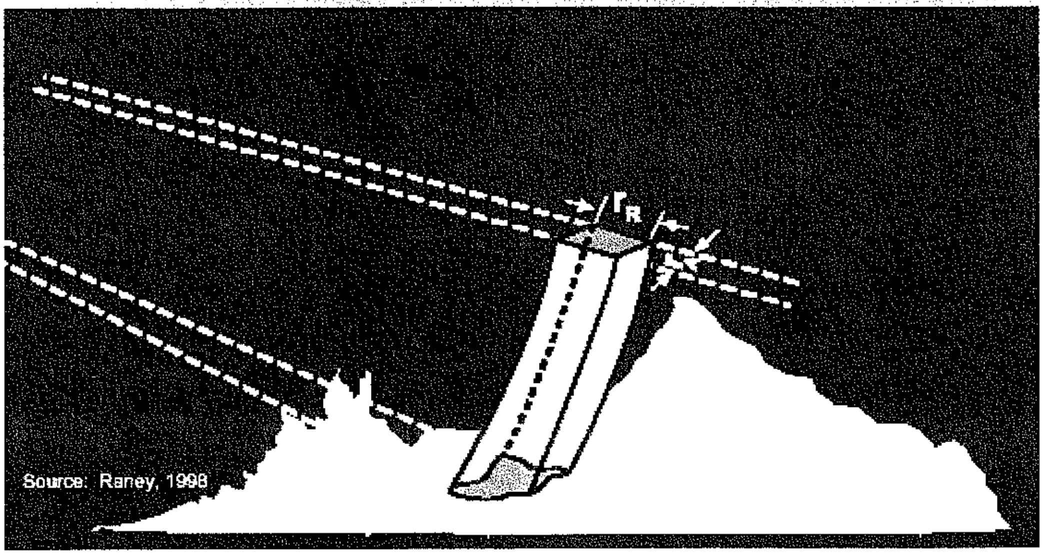
A simple (*i.e.* real-aperture) radar has an azimuth resolution given by the azimuth beam width

A synthetic aperture radar (SAR) uses signal processing to refine the azimuth resolution to shorter than the antenna length



32

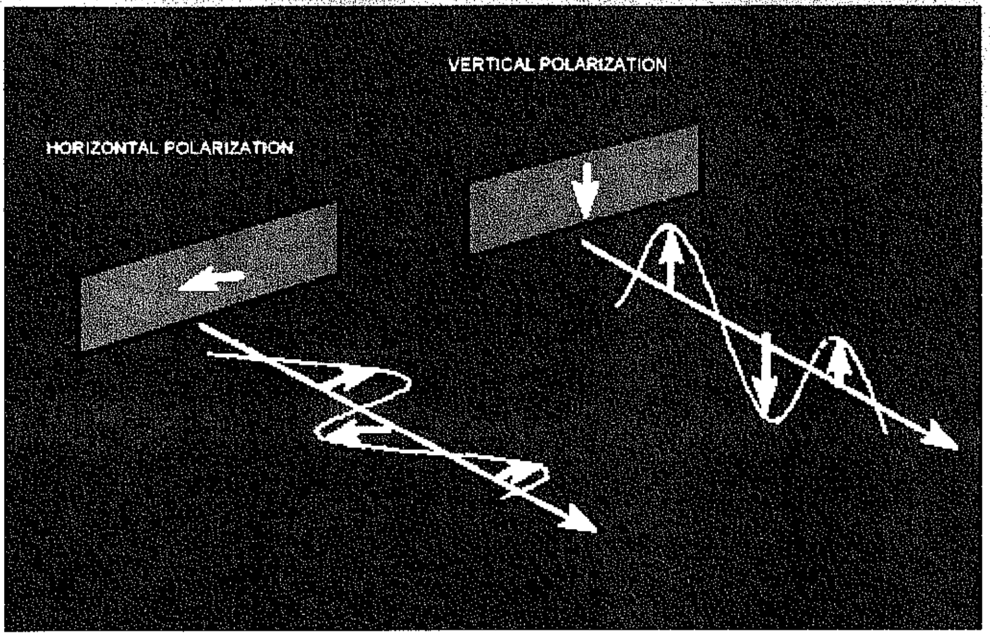
Resolution Cell



r_R = range resolution r_A = azimuth resolution

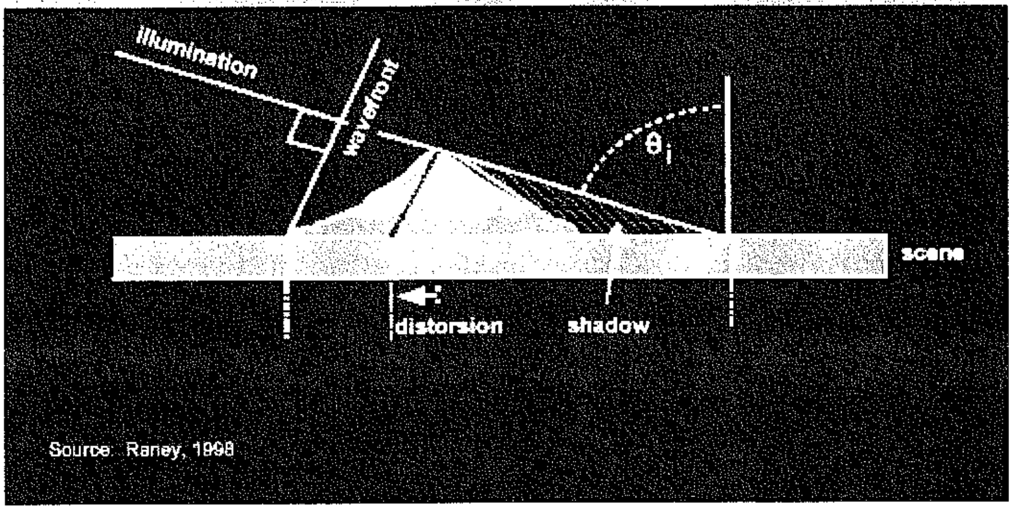
(32)

EM Wave Polarization
Electrical Field



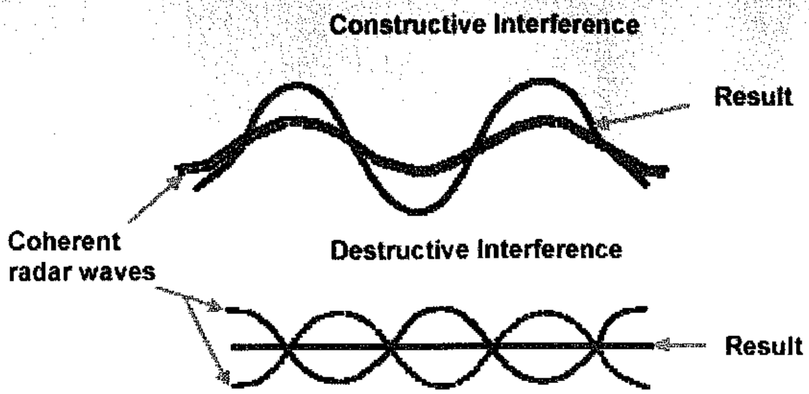
(33)

Radar Shadow

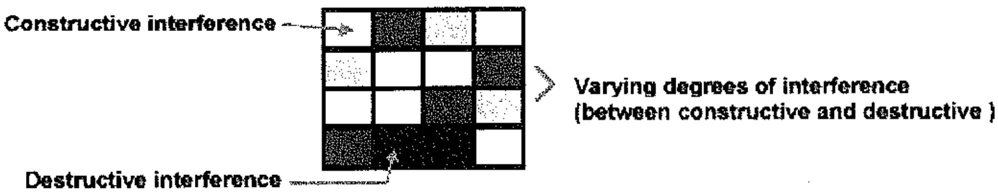


(34)

Speckle



Example of Homogenous Target



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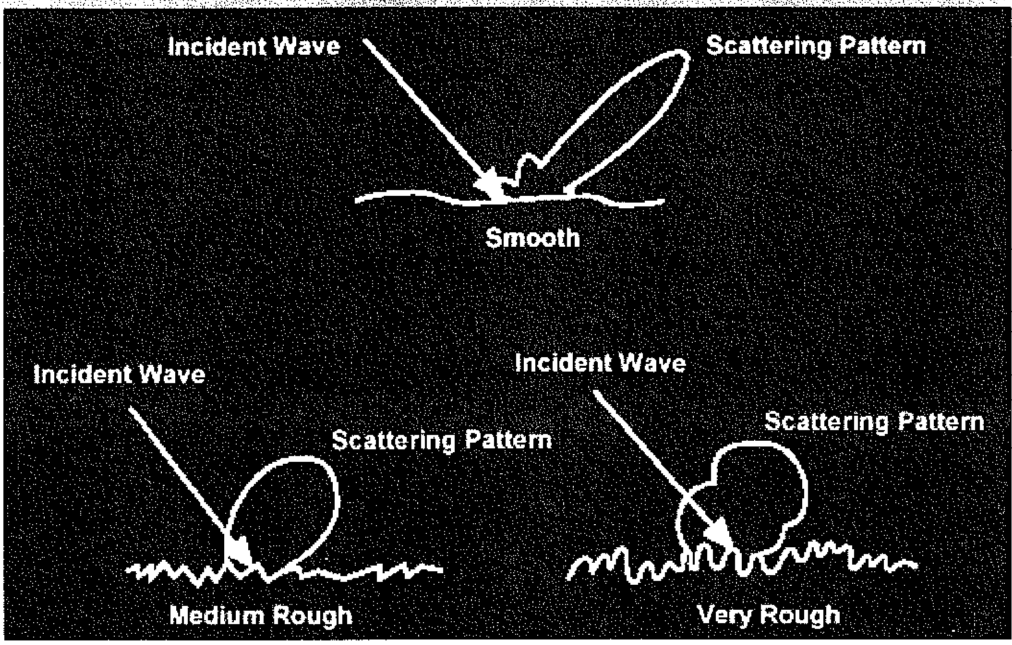
Surface Roughness
Surface Scattering Patterns



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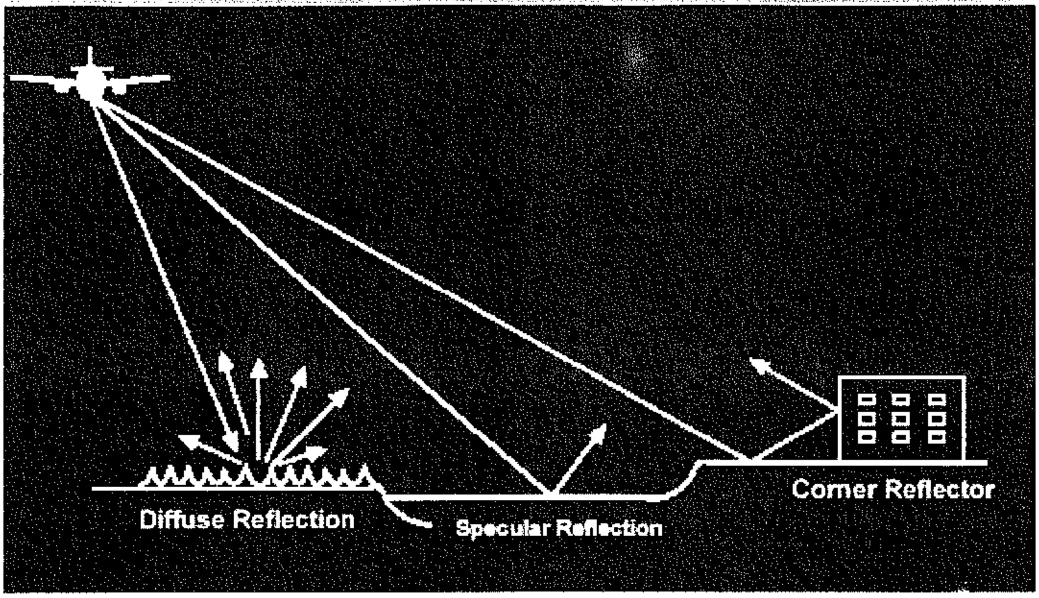
Diffuse and Specular Reflectance



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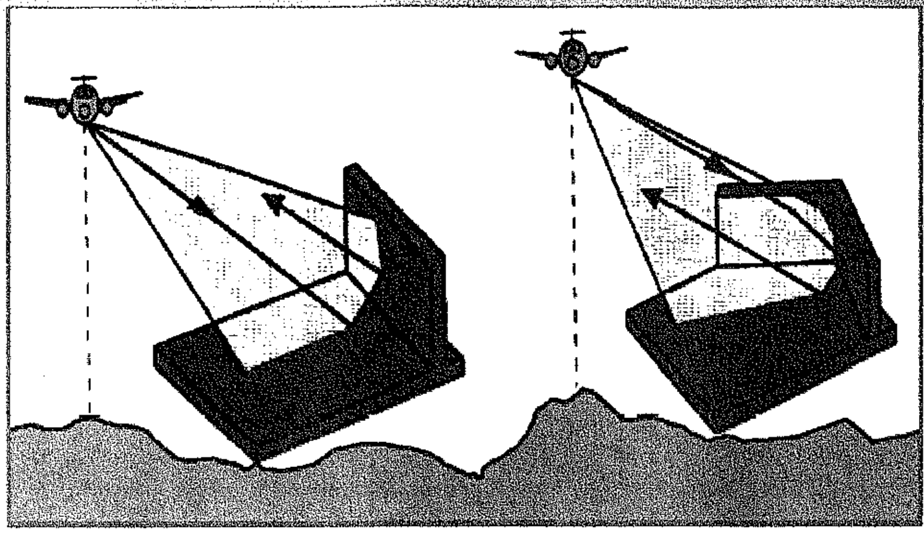
Corner Reflectors



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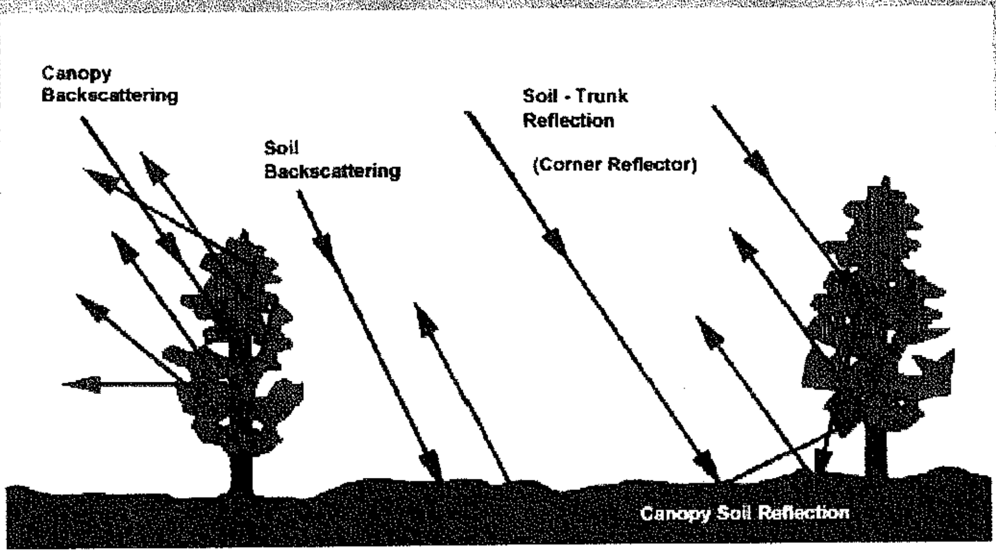
Reflections



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RADARSAT-1

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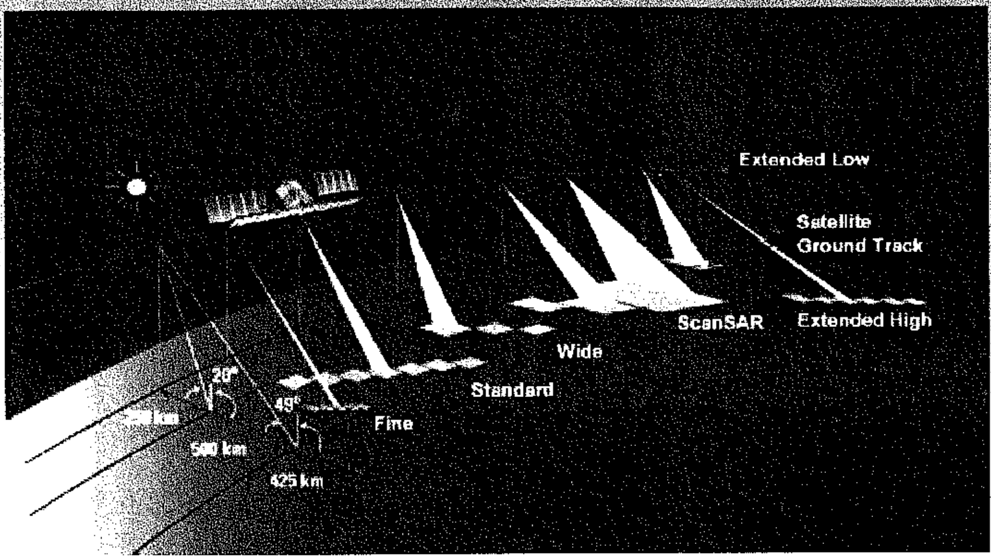
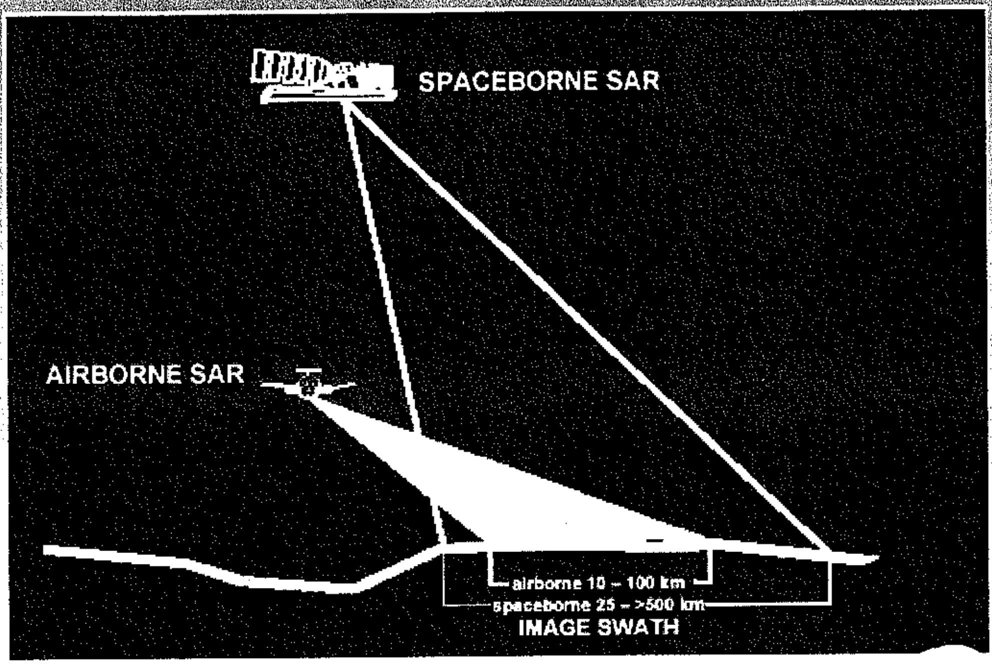
RADARSAT-1 SAR Imaging Modes



Comparison of Imaging Geometries



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