INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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H4.SMR/383 - 07

WORKSHOP ON REMOTE SENSING TECHNIQUES WITH APPLICATIONS TO AGRICULTURE, WATER AND WEATHER RESOURCES

(27 February - 21 March 1989)

OPERATIVE SENSORS

OPERATIVE SATELLITES

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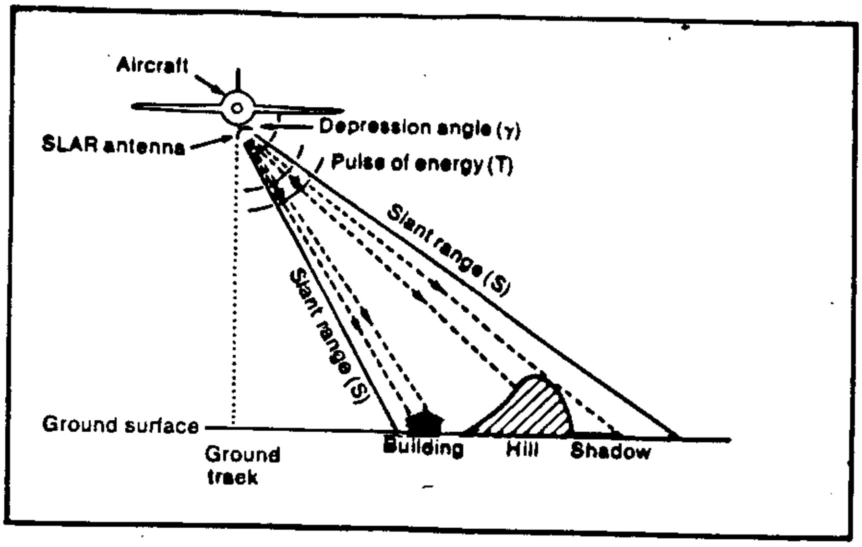


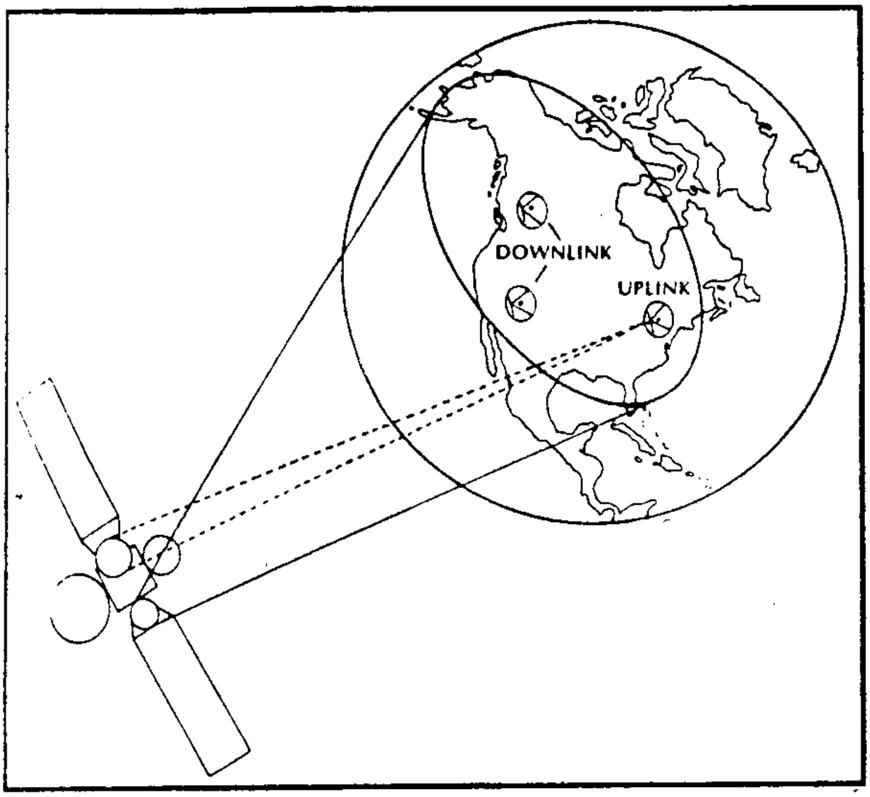
Schematic illustration of a side-looking airborne radar (SLAR)

Wavebands commonly used in radar remote sensing

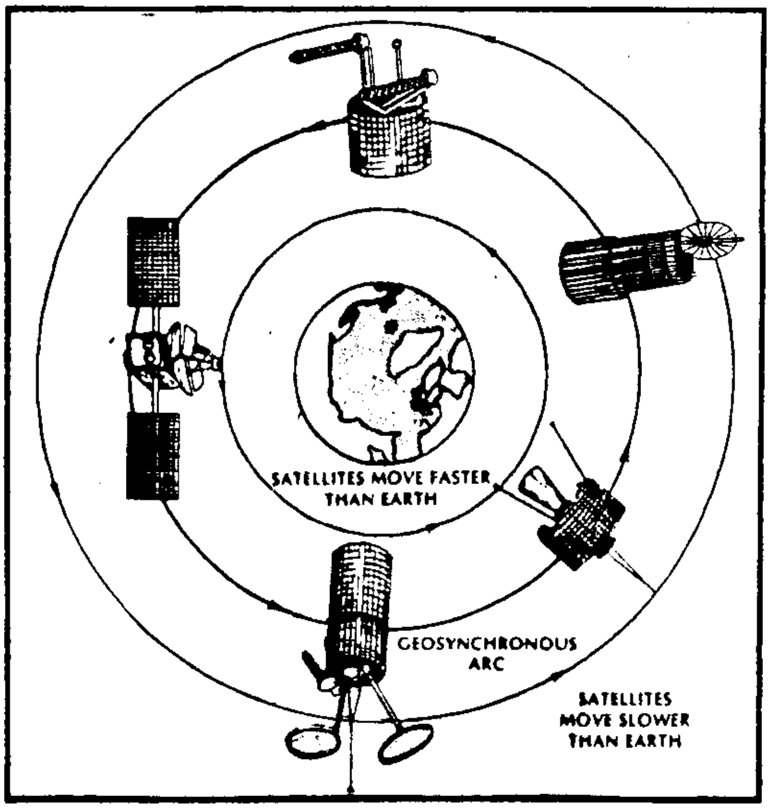
Band designation	*Wavelength range (mm)*	*Frequency (GHz)*
Ka	8–11	28–37.5
K	11–17	18–28
X	24–38	8–12.5
C	38–75	4–8
L	150–300	1–2

Polarisation combinations for radar

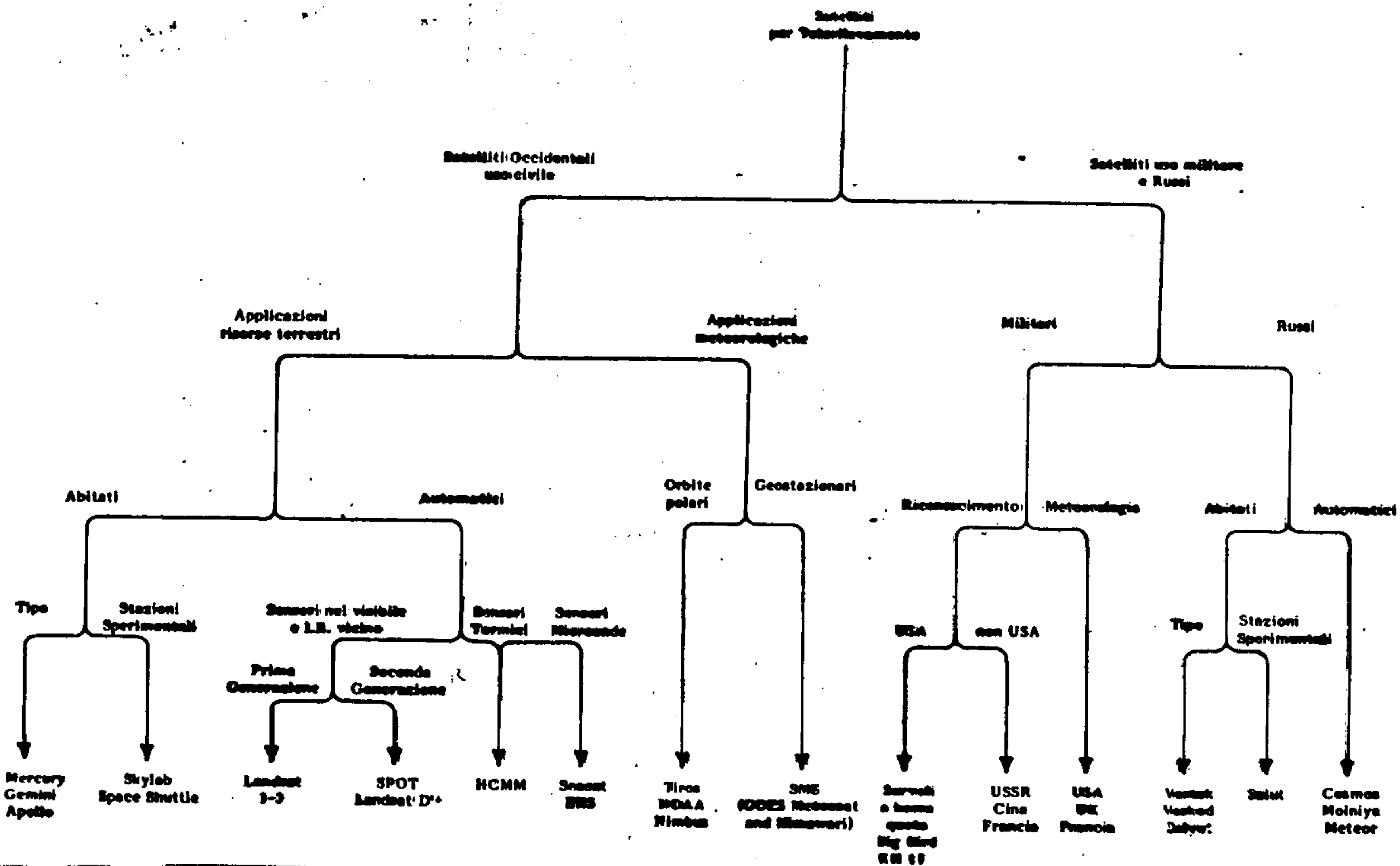
Transmitted energy		*Received energy*	
Horizontal	HH	Horizontal	Like polarisation
Vertical	VV	Vertical	Like polarisation
Horizontal	HV	Vertical	Cross polarisation
Vertical	VH	Horizontal	Cross polarisation



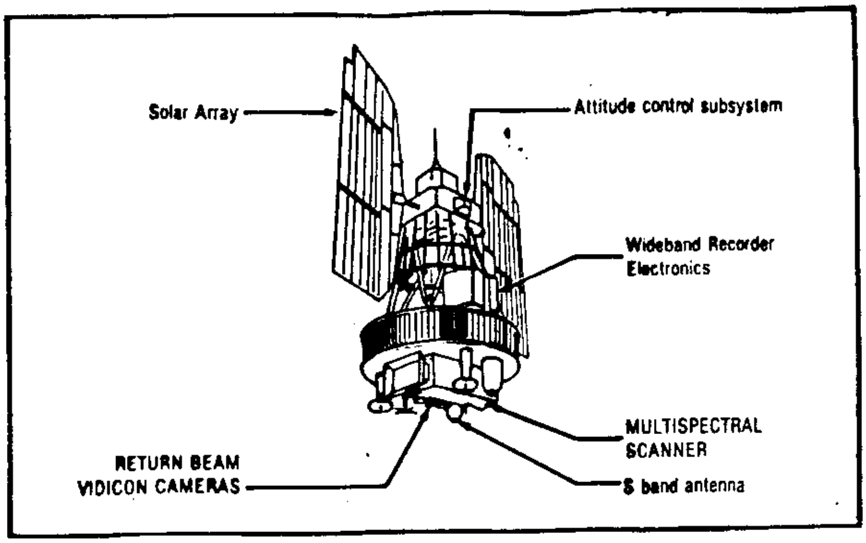
The Satellite Communication Circuit. *All satellite signals must be uplinked from a high power amplifier (HPA), channeled into a feedhorn and reflected from the antenna towards the communication satellite. The signal is received by the spacecraft's antennas, amplified, lowered in frequency and redirected back to earth. Typical Ku-band uplink frequencies are 14.0 to 14.5 GHz. In North America, FSS downlink frequencies are 11.7 to 12.2 GHz for satellites orbiting from 57 to 146 degrees West. Different downlink frequency ranges have also been allocated.*



The Geosynchronous Arc. *Sate[illegible] in higher or lower positions than the geosta[illegible] ary orbit of 35,803 kilometers (22,247 m[illegible] over the equator will rotate more slow[illegible] quickly, respectively, than the speed of the [illegible] below. Only satellites in the geostationary [illegible] appear to stay in a fixed position relative [illegible] observer on the earth below.*



Satelliti
per Telerilevamento
Satelliti Occidentali
uso civile
Satelliti uso militare
e Russi
Applicazioni
risorse terrestri
Applicazioni
meteorologiche
Militari
Russi
Abitati
Automatici
Orbite
polari
Geostazionari
Riconoscimento
Meteorologia
Abitati
Automatici
Tipo
Stazioni
Sperimentali
Sensori nel visibile
e I.R. vicino
Sensori
Termici
Sensori
Microonde
USA
non USA
Tipo
Stazioni
Sperimentali
Prima
Generazione
Seconda
Generazione
Mercury
Gemini
Apollo
Skylab
Space Shuttle
Landsat
1-3
SPOT
Landsat D'+
HCMM
Seasat
Tiros
NOAA
Nimbus
SMS
(GOES Meteosat
and Himawari)
USSR
Cina
Francia
USA
UK
Vostok
Voskod
Salut
Cosmos
Molniya
Meteor



The first generation Landsat platform

Operation periods of the Landsat 1–3 satellites

Satellite	*Launch date*	*End of operation*
Landsat 1	23 July 1972	6 January 1978
Landsat 2	22 January 1975	27 July 1983*
Landsat 3	5 March 1978	7 September 1983**

Source: NOAA (1986)

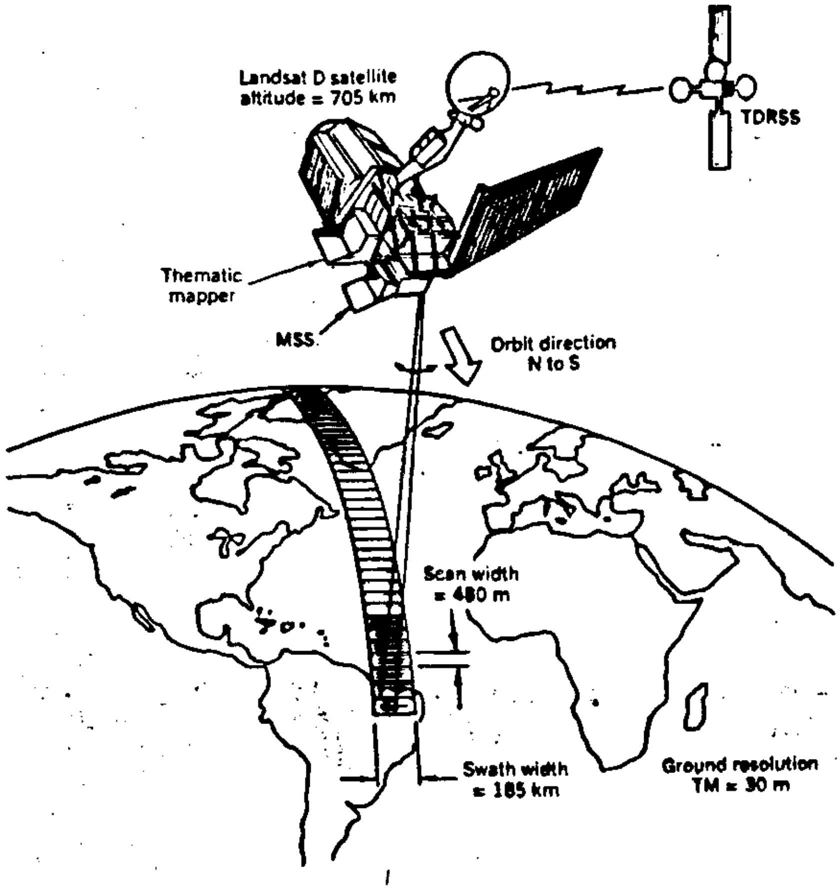
*Interruption in 1979–80

**Standby mode from 31 March 1983

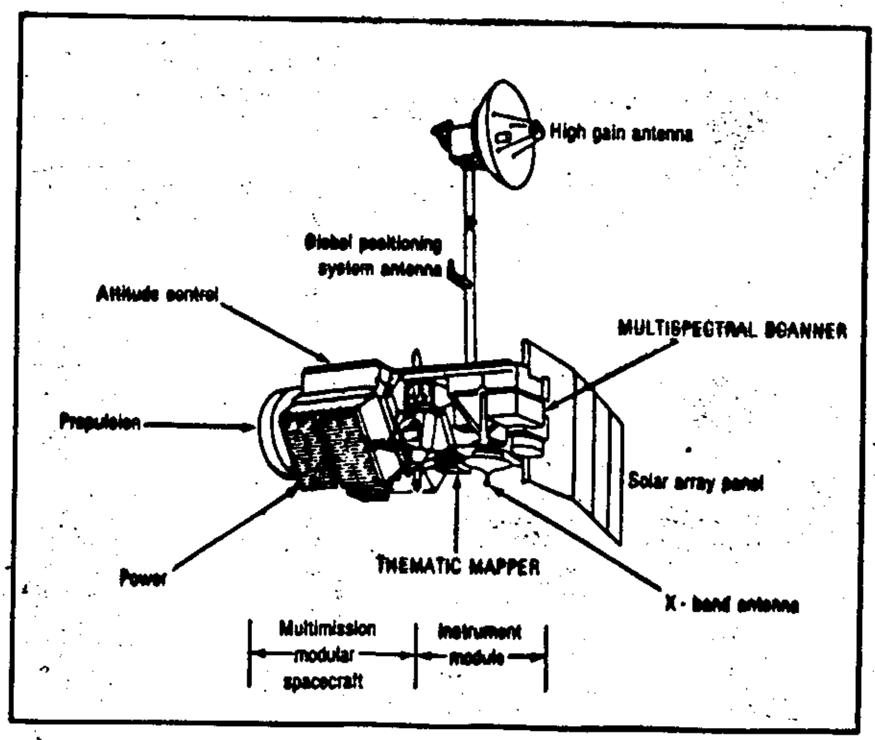
Wavebands of the Landsat Multispectral Scanner

Band	*Wavelength range (μm)*	*Applications*
4	0.5–0.6	Sediment loads; shallow water
5	0.6–0.7	Vegetation; cultural features
6	0.7–0.8	Land/water separation
7	0.8–1.1 (1.0*)	Vegetation and geological studies

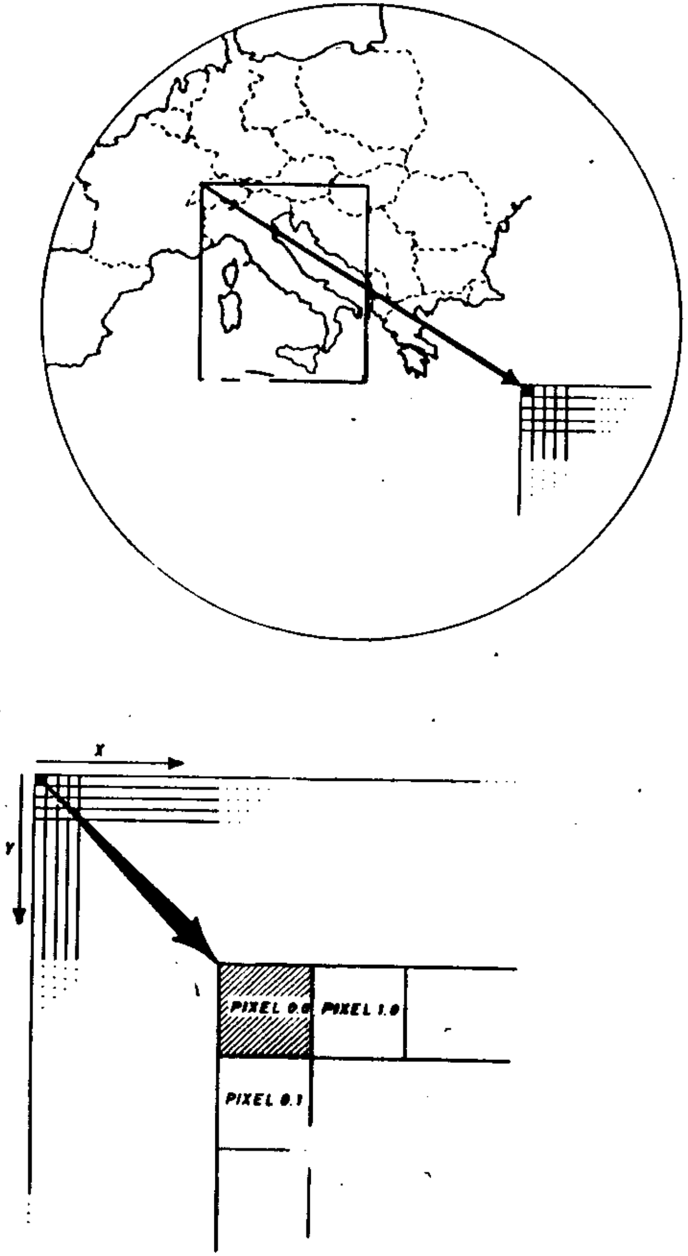
*The upper limit of band 7 is normally quoted as 1.1μm, but has also been quoted as 1.0μm



Landsat-D mission.



The second generation Landsat platform



1 - Le immagini riprese dallo spazio dai satelliti artificiali sono costituite da elementi finiti chiamati pixel (= Picture element) ciascuno dei quali è caratterizzato dalla sua posizione sull'immagine e da un numero che rappresenta l'intensità della radianza al suolo; questo per ciascuna delle bande di ripresa.

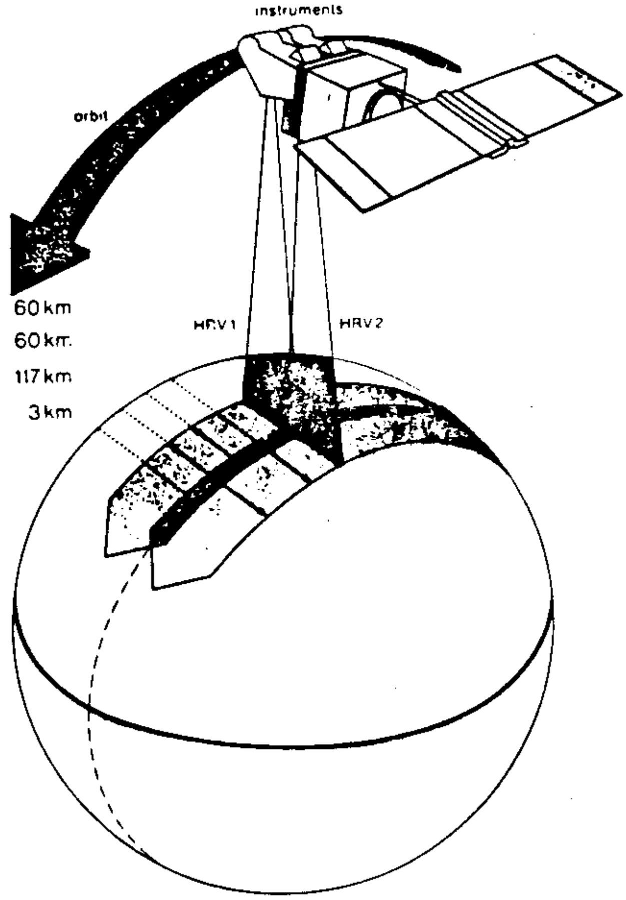


FIG. 23 - Sistema di visione in cui lavorano in parallelo i due HRV.

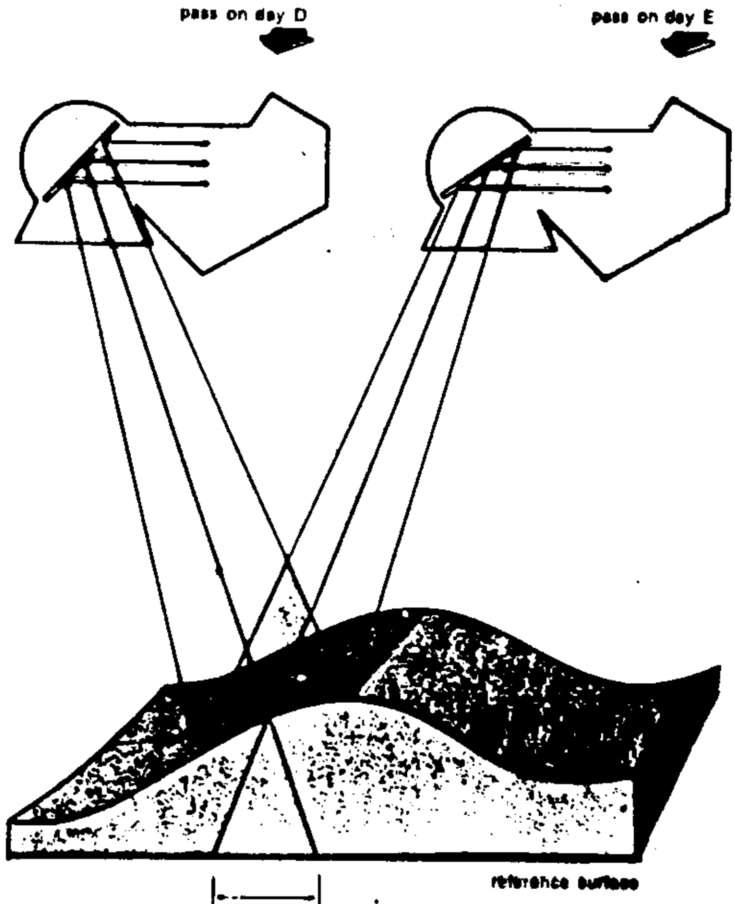
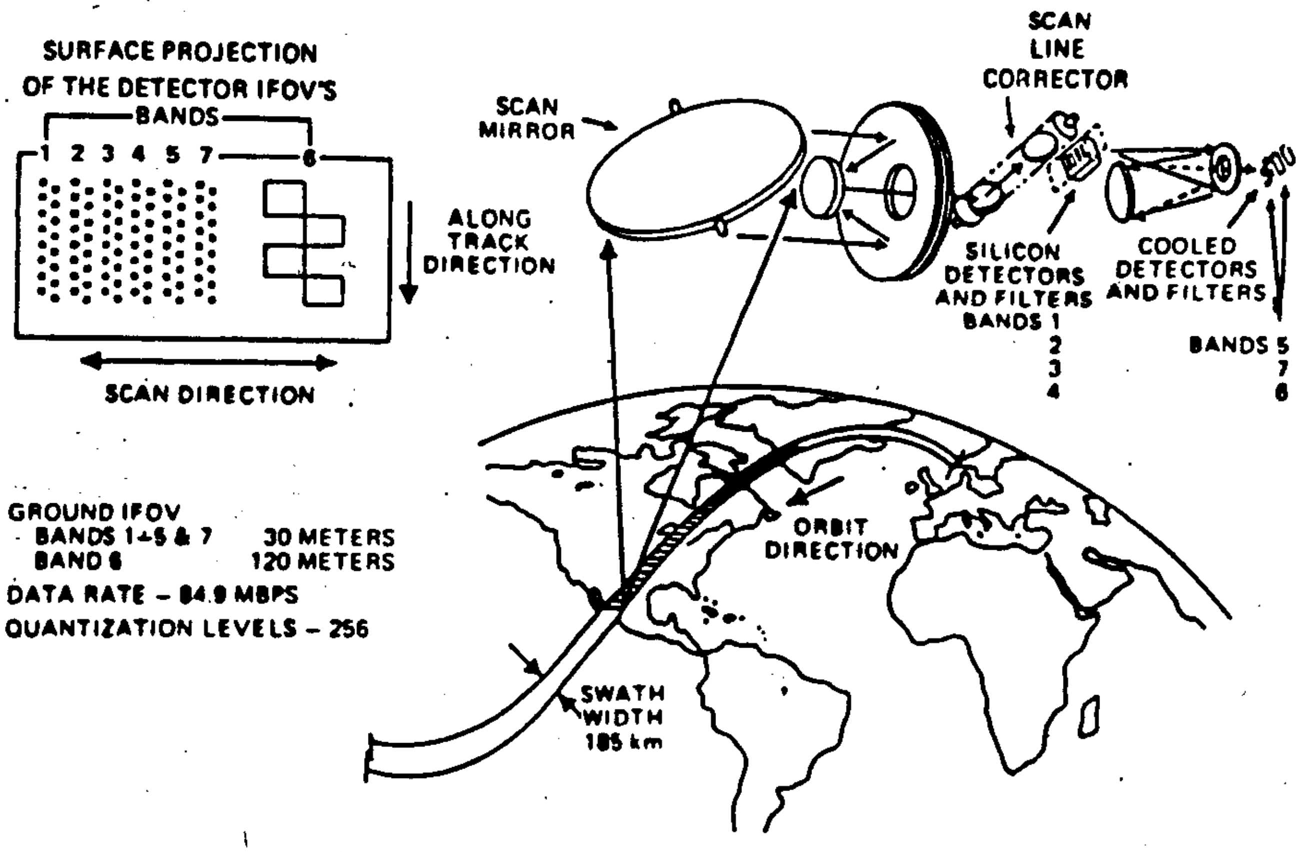
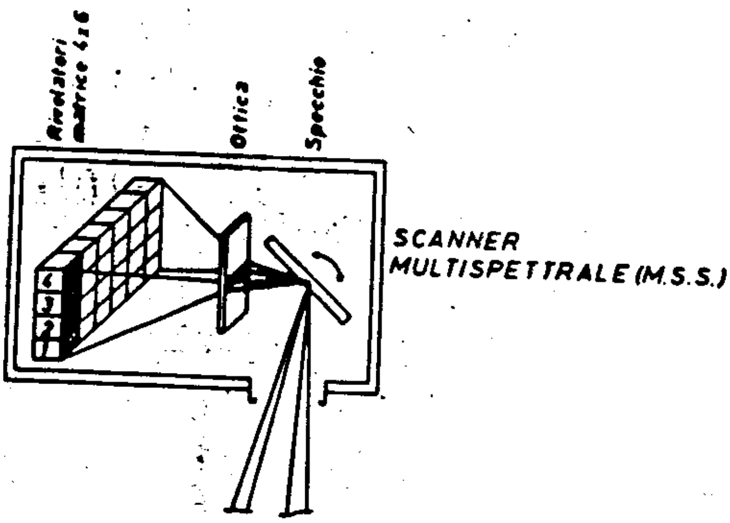
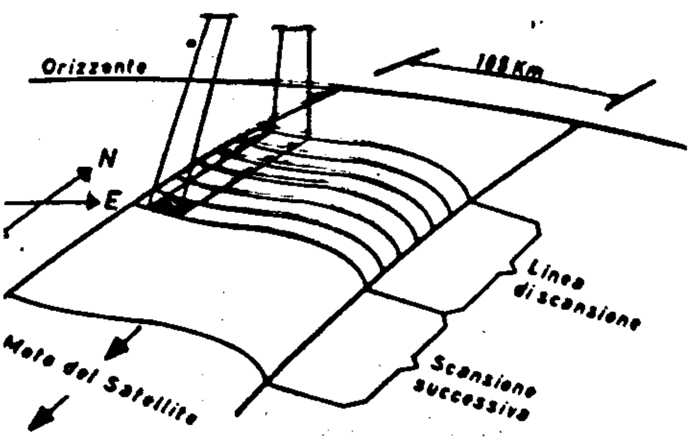


FIG. 24 - Possibilità di ripresa stereoscopica del sistema SPOT, con visione laterale della stessa zona da due orbite diverse con due diversi angoli di ripresa.

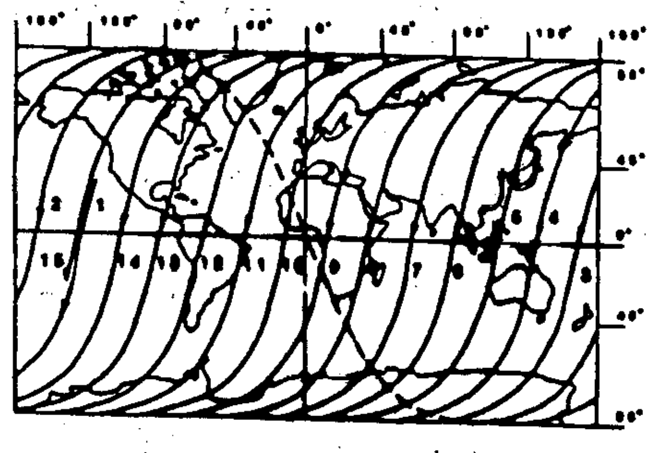


· Schema di principio di funzionamento dello scanner TM (Landsat 4,5). (Figura tratta da NASA Technical memo n. 86149).

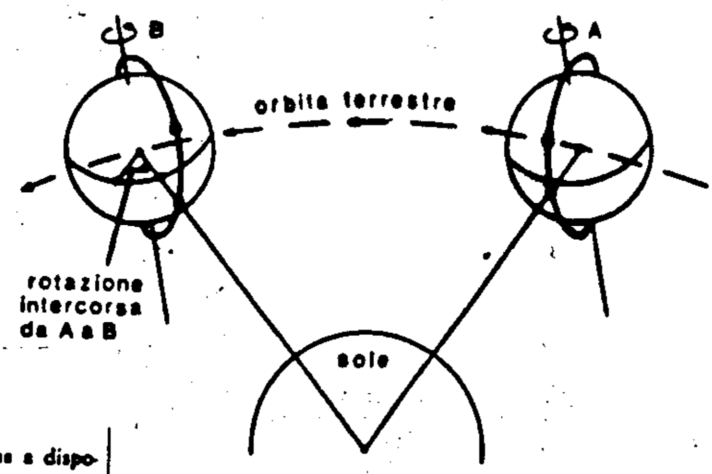




...ma di principio della scansione MSS Landsat: ciascuna delle 4 bande ha a dispo-
...one 6 rivelatori.



In questa figura sono rappresentati i tracciati delle orbite Landsat (1, 2, 3) relative a 24 ore (14 orbite complete). In tratteggio è riportata una delle orbite « notturne ».



Precessione delle orbite che forniscono ...

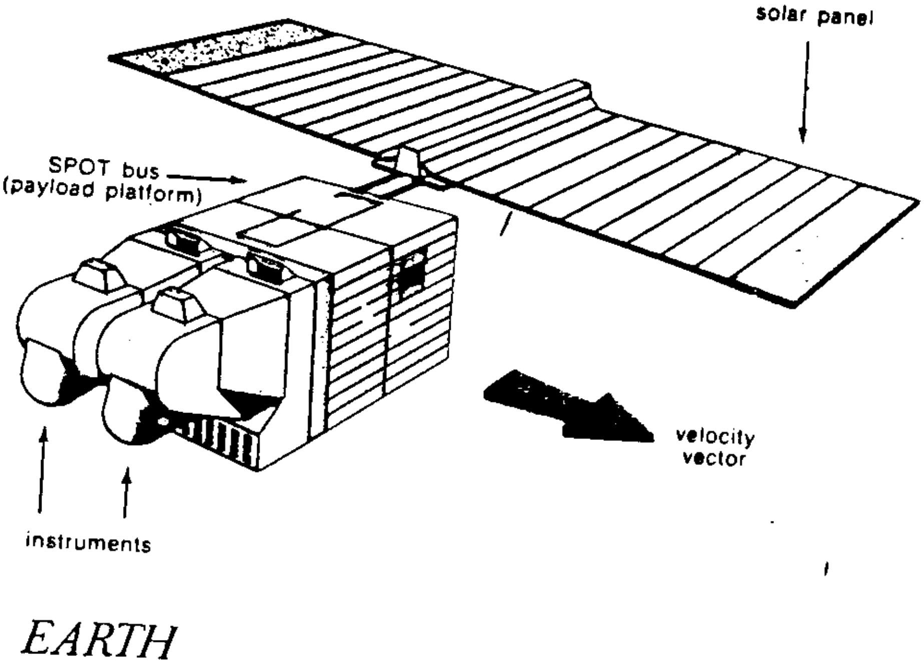


FIG. 20 - Il satellite SPOT.

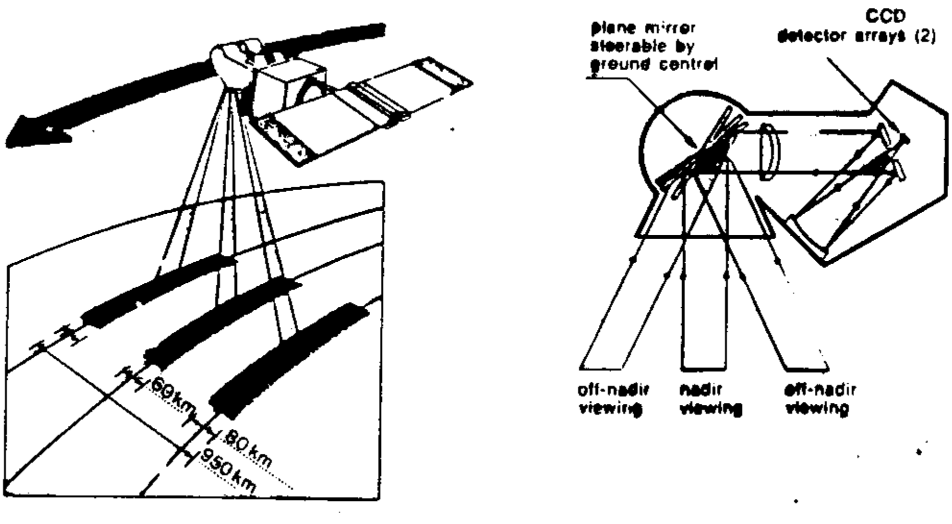
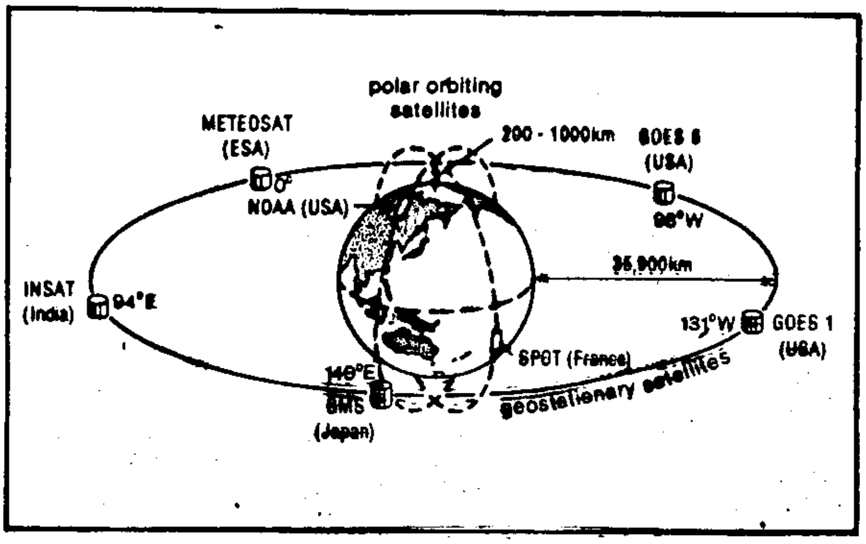


FIG. 22 - Possibilità di visione off-axis (±27°) del sistema SPOT.

Meteosat wavebands

Band	*Wavelength range (µm)*	*Resolution (km) at 0° latitude 0° longitude*
Visible/near infrared	0.4–1.1	2.5
Water vapour	5.7–7.1	5.0
Thermal infrared	10.5–12.5	5.0



Polar and geostationary orbits used for meteorological and Earth observation satellites. (Modified from ESA 1985)

Characteristics of the Multispectral Scanner (MSS) and Thematic Mapper (TM) carried on Landsats 4 and 5

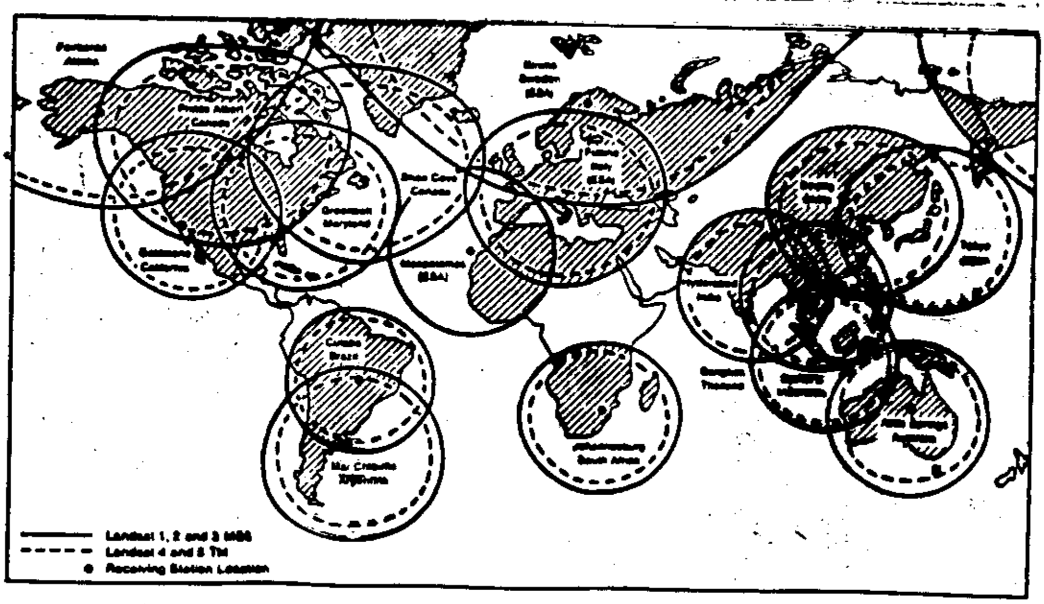
Band	*MSS wavelength range (μm)*	*TM wavelength range (μm)*	*Principal applications for TM data*
1	0.5–0.6	0.45–0.52	Coastal water mapping Soil/vegetation differentiation
2	0.6–0.7	0.52–0.60	Green reflectance by healthy vegetation
3	0.7–0.8	0.63–0.69	Chlorophyll absorption for plant species differentiation
4	0.8–1.1 (1.0)	0.76–0.90	Biomass surveys
5		1.55–1.75	Vegetation moisture Snow/cloud discrimination
6		10.4–11.7*	Thermal mapping including plant stress
7		2.08–2.35	Vegetation moisture and geological mapping
Ground pixel size	82m	30m (Bands 1–5, 7) 120m (Band 6)	
Quantization levels	64	256	
Data rate	15 Mbps	85 Mbps	
Weight	68kg	258kg	
Size	0.35 × 0.4 × 0.9m	1.1 × 0.7 × 2m	
Power	50 watts	332 watts	

Sources: Freden and Gordon (1983), National Remote Sensing Centre (1985). See also Markham and Barker (1985a, b)

*Prelaunch calibration showed this wavelength range. The design range was 10.4–12.5μm

Principal recent and current satellite remote sensing systems

Satellite Instrument(s) Country	*Launch date(s)*	*Image repeat possibility*	*Wavelength(s)/ frequency*	*Spatial resolution*	*Swath width*	*Main applications*
GOES series Visible and Infrared Spin-Scan Radiometer (VISSR) USA	Series from October 1975	19 minutes	Visible Thermal IR	0.8km 6.9km	Full Earth disc or quarter disc	Meteorology
Meteosat series Radiometer Meteosat 1 Meteosat 2 ESA	 November 1977 June 1981	30 minutes	Visible Middle IR Thermal IR	2.4km 5km 5km	Full Earth disc or sectors	Meteorology Vegetation Environmental hazards
GMS series (Himawari) Visible and Infrared Spin-Scan Radiometer Japan	Series from July 1977	30 minutes	Visible Thermal IR	1.25 or 4km 5 or 7km	Full Earth disc or quarter disc	Meteorology
Insat I series Very High Resolution Radiometer India	IA April 1982 (abandoned September 1982) IB August 1983	30 minutes	Visible Thermal IR	2.75km 11km	Full Earth disc	Meteorology
Tiros-N/Noaa series Advanced Very High Resolution Radiometer (AVHRR) USA	Series from October 1978	12 hours	Visible Near IR Middle IR Two thermal IR bands	1.1km	2,400km	Meteorology Oceanography Hydrology Vegetation
Tiros-N/Noaa series Tiros Operational Vertical Sounder (TOVS) USA	Series from October 1978	12 hours	Twenty IR bands Three IR bands Four micro-wave bands	17.4km 147.3km 105km (at nadir)		Meteorology
Defense Meteoro-logical Satellite Program (DMSP) Operational Linescan System (OLS) USA	Block 5D series from September 1976	12 hours	Visible and thermal IR	0.6km		Meteorology



The Landsat receiving stations and their coverage areas

Satellite *Instrument(s)* *Country*	*Launch date(s)*	*Image repeat possibility*	*Wavelength(s)/ frequency*	*Spatial resolution*	*Swath width*	*Main applications*
Meteor series USSR	Series from 1969	12 hours	Visible Thermal IR			Meteorology
Kosmos series Multispectral scanner Kosmos 1500 Kosmos 1602 USSR	September 1983 September 1984	3 days	Four bands visible and near IR	1.5km	1930km	Meteorology Land applications
Landsat series USA Multispectral scanner (MSS) Landsat 1 Landsat 2 Landsat 3 Landsat 4 Landsat 5	July 1972 January 1975 March 1978 July 1982 March 1984	18 days 18 days 18 days 16 days 16 days	Four bands in visible and near IR Thermal IR (Landsat 3 only)	79m 237m	185km	Land use Vegetation Geology Geomor-phology Hydrology
Landsat 4 Landsat 5 Thematic Mapper (TM)	July 1982 March 1984	16 days 16 days	Six bands visible, near and middle IR Thermal IR	30m 120m	185km	Land use Vegetation Geology Geomor-phology Hydrology Cartography
SPOT High Resolution Visible (HRV) France	February 1986	2.5 days (off-nadir)	Visible Near IR Panchromatic	20m 10m	60km	Land use Agriculture Cartography Exploration
Seasat Synthetic Aperture Radar (SAR) USA	June 1978	Limited cover	23.5cm (L-band)	25m	100km	Oceanography
Space Shuttle Shuttle Imaging Radar SIR-A SIR-B USA	November 1981 October 1984	Limited cover	23cm (L-band)	40m 30m	50km 20–50km	Geology Geomor-phology Soils Land use Oceanography
Space Shuttle Metric Camera ESA	November 1983	Limited cover	Panchromatic	c.20m	190km Stereo	Topographic mapping (1:50,000–1:100,000 scales)
Space Shuttle Large Format Camera USA	1984	Limited cover	Panchromatic Colour Near IR	c.20m		Cartography (1:50,000 scale)
Space Shuttle MOMS West Germany	June 1983 February 1984	Limited cover	Visible Near IR Thermal IR	10–20m	140km Stereo	Vegetation Land use Hydrology Geology

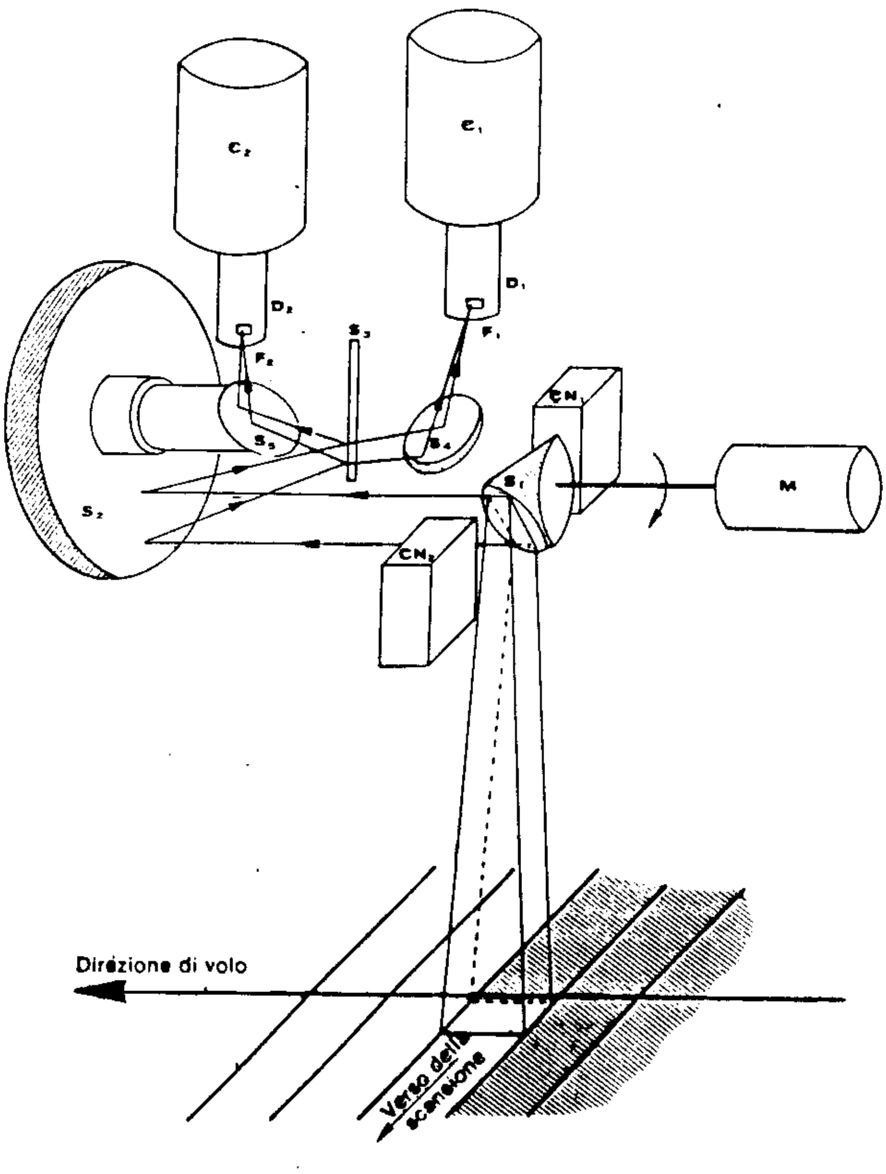


Fig. 5 — Schema di scansione ottico-meccanica. L'energia raccolta dallo specchio rotante S1 (mosso dal motore M) è rinviata attraverso la serie di specchi fissi S2-S5 ai due detectors D1 e D2 termostatati dai sistemi C1 e C2. Lo specchio dicroico S_3 separa la radianza in due campi di lunghezza d'onda contigui. CN1 e CN2 sono due riferimenti costituiti dai corpi neri di calibrazione.

Costi approssimativi delle immagini

Si portano alcune considerazioni relative ai costi e costi per ettaro delle immagini più frequentemente utilizzate; poiché i prezzi sono soggetti a variazione si riportano cifre (1985) che non vanno prese come assolute:

1) Immagine digitale TM completa (7 bande)	= L. 7.300.000
2) ¼ immagine digitale TM completa (7 bande)	= L. 2.000.000
3) Immagine digitale MSS completa (4 bande)	= L. 1.200.000
4) Negativo (1 banda 240 m) TM ¼ immagine	= L. 200.000
5) Negativo (1 banda 240 mm). MSS	= L. 100.000

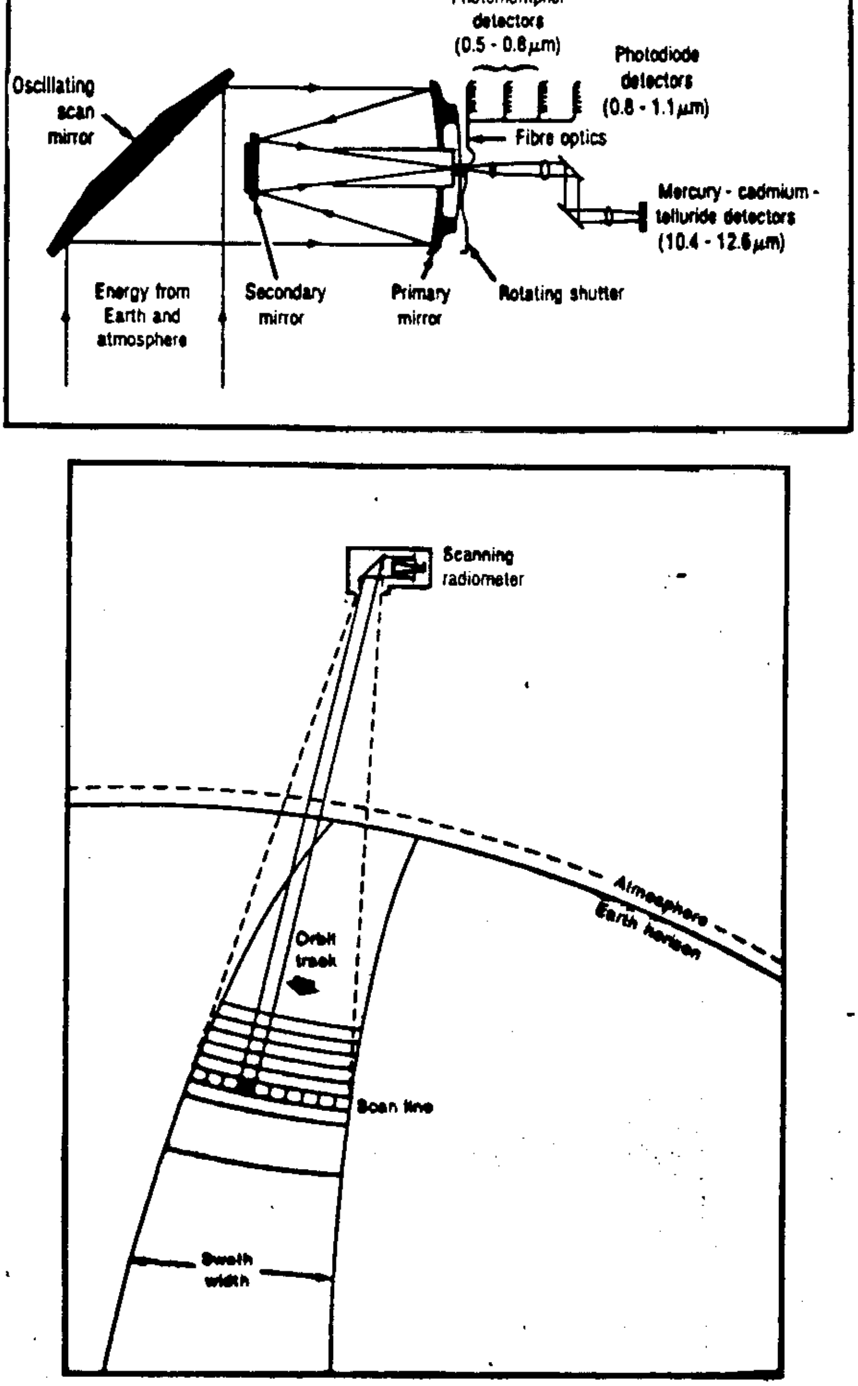
Sulle base di queste cifre si può ottenere una indicazione del costo/ettaro

	Superficie (Ha)	Lire/Ha
1)	3.422.500	2.13
2)	850.000	2.35
3)	3.422.500	0.35
4)	850.000	0.23
5)	3.422.500	0.03.

Questi costi — oltre ad essere approssimativi — non tengono conto del fatto che:

- — Per le immagini digitali è necessario un centro di calcolo (spesa di investimento) per il funzionamento del quale si deve tener conto delle spese di gestione, spese per contratto di assistenza, ammortamento ecc. Non solo, ma anche l'acquisto o la produzione di software di trattamento vanno conteggiati in questa fase.
- — Per le immagini su supporto fotografico è necessaria una camera scura dotata di attrezzature opportune all'uopo e di tutto il materiale chimico per i trattamenti.
- — Per elaborare le immagini digitali o fotografiche occorre personale specializzato, il cui costo incide comunque sul costo globale del risultato finale.

Sorge spontaneo un confronto con i costi/ettaro delle immagini tradizionali riprese da aereo, ma una comparazione con esse è praticamente impossibile, data la natura profondamente diversa delle caratteristiche dei due modi di ripresa: in questa sede pertanto non si ritiene competitivo l'un metodo rispetto all'altro ma si sottolinea che — posto un problema di ripresa — adottare una tecnica di ripresa o l'altra dipende essenzialmente dal risultato che si vuole ottenere e dalle specifiche esigenze del problema.



Schematic diagram of the Landsat 3 Multispectral Scanner scanning radiometer (top) and its orbital scanning pattern. (In part after Freden and Gordon 1983)

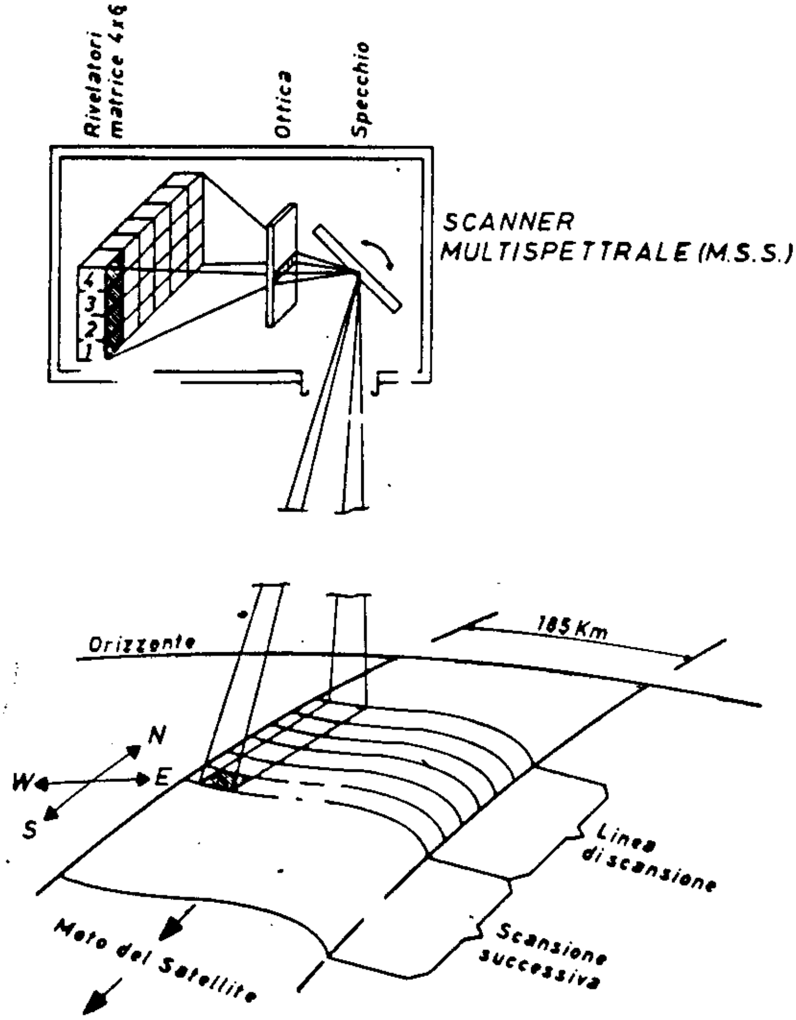


FIG. 16 - Schema di principio della scansione MSS Landsat: ciascuna delle 4 bande ha a disposizione 6 rivelatori.

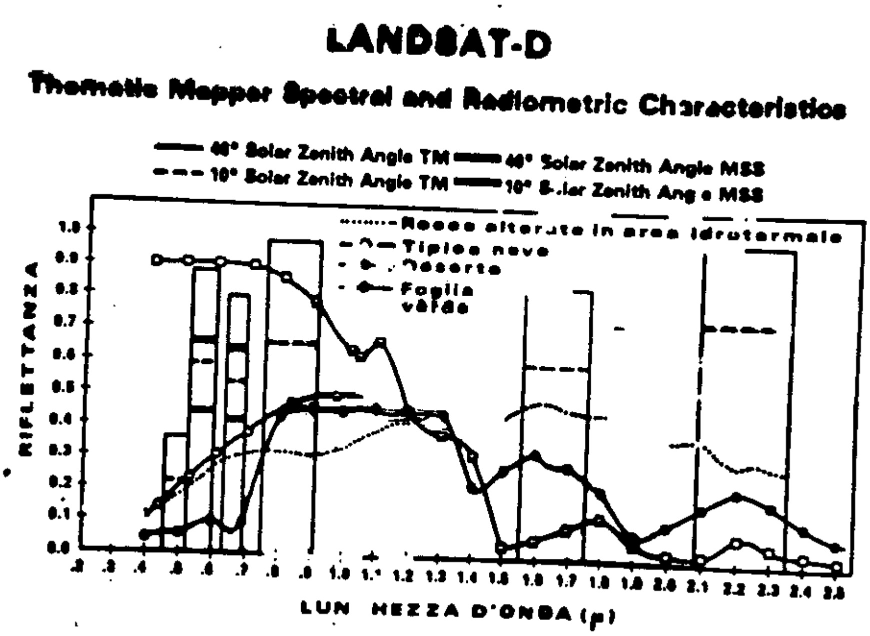
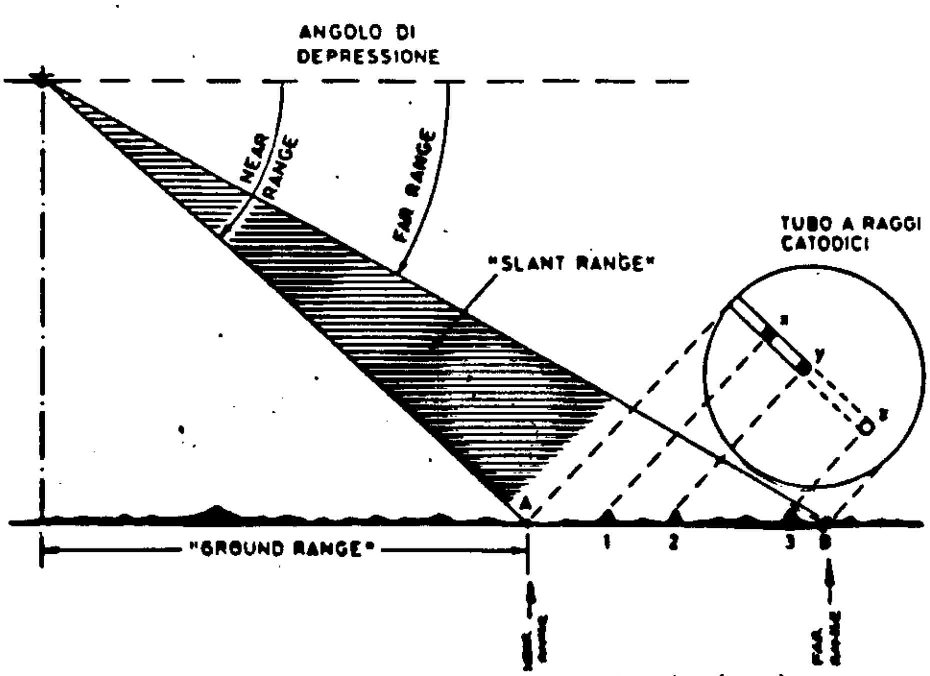
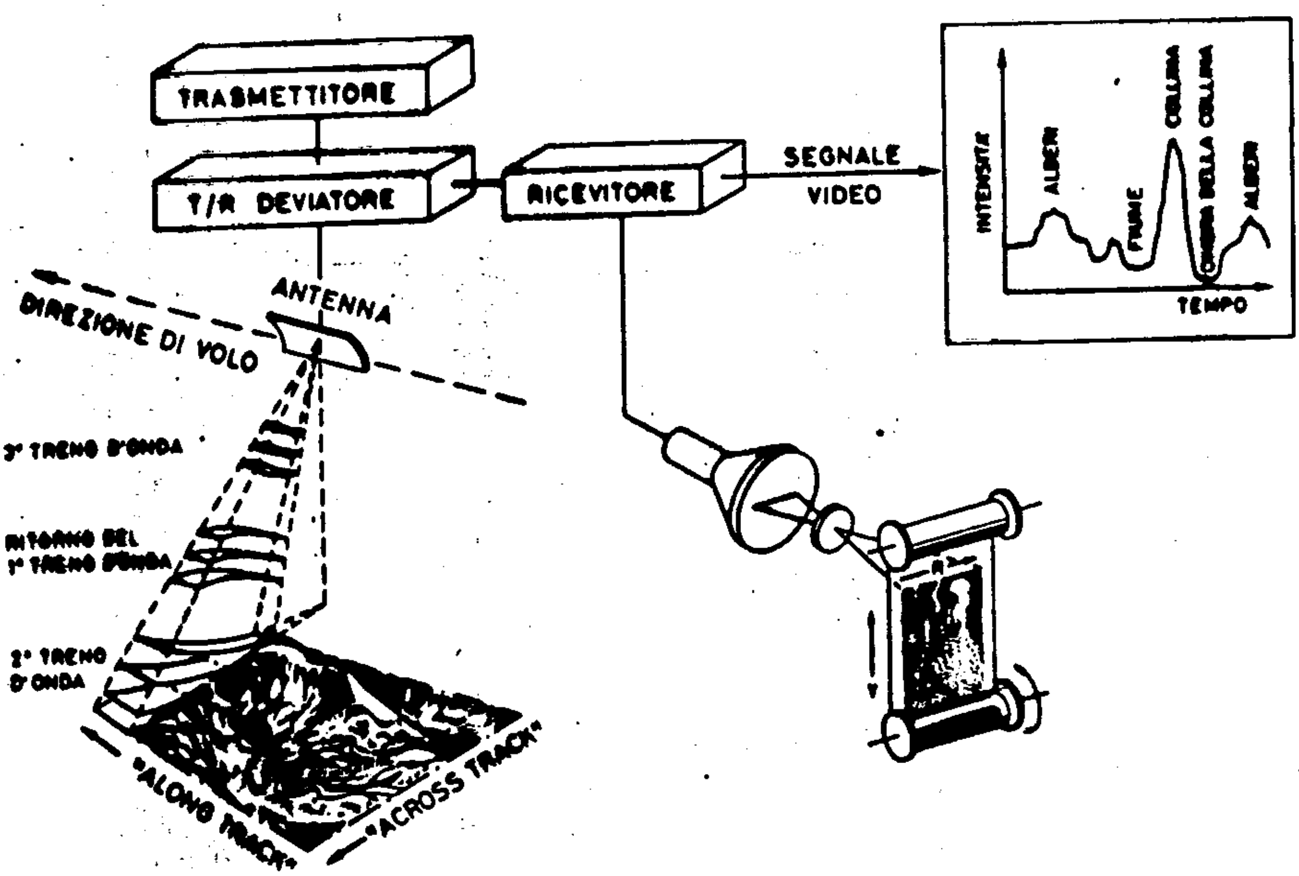


FIG. 18 - In questa figura sono rappresentate le bande 1, 2, 3, 4, 5, 7 del TM, la loro posizione sullo spettro e la loro larghezza. (Figura tratta dal Manual of Remote Sensing).



Conversione sul tubo a raggi catodici di un impulso radar.



Configurazione elementare di un sistema radar