Remote Sensing

Remote Sensing
Literature:

- Lillesand T.M. and Kiefer R.W., 2000. Remote sensing and image interpretation. John Wiley & Sons.
- Aronoff S., 2005. Remote sensing for GIS managers; ESRI Press, Redlands, California.
- Barrett E.C. and Curtis L.F., 1992. Introduction to environmental remote sensing. Chapman & Hall.
- Jensen J.R., 2000. Remote sensing of the environment. An earth resource perspective. Prentice Hall, Upper Saddle River, New Jersey.

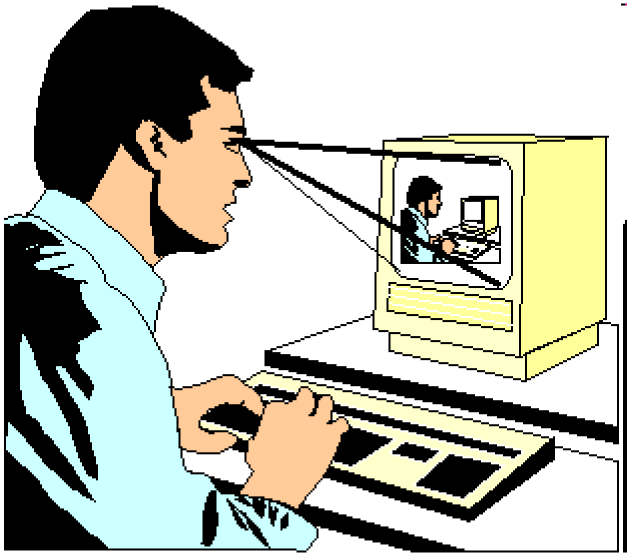
Remote Sensing
Table of contents

Remote Sensing - introduction

REMOTE SENSING DEFINITIONS:

The more general: **Remote Sensing involves gathering data and information about the physical "world" by detecting and measuring signals composed of radiation, particles, and fields emanating from objects located beyond the immediate vicinity of the sensor device(s).**

The more restricted: **Remote Sensing is a technology for sampling electromagnetic radiation to acquire and interpret non-contiguous *geospatial data* from which to extract information about features, objects, and classes on the Earth's land surface, oceans, and atmosphere**



"Remote" and "Proximal" Sensing

Nicholas Short Tutorial of Remote Sensing (http://rst.gsfc.nasa.gov/Intro)

Remote Sensing - introduction

Remote Sensing methods:

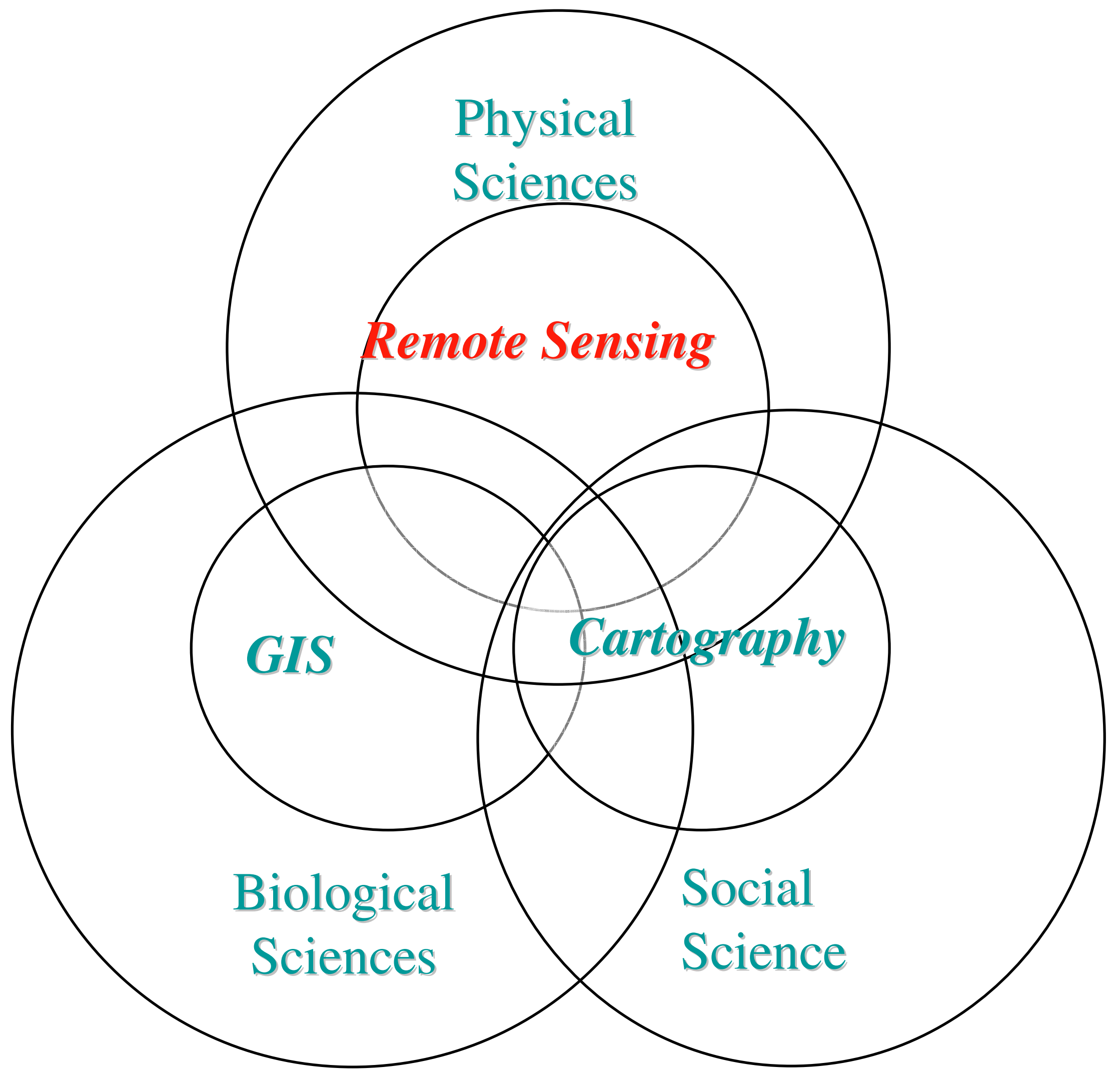
- passive analog (camera, videography)
- passive digital (camera, multispectral scanners, linear and area arrays, spectroradiometers)
- active (microwave - radar, laser - lidar, sonar)

Remote Sensing observations can be carried out from a level:

- Satellite,
- Airborne,
- Low Altitude Remote Sensing (LARS)
- Ground.

Remote Sensing - introduction

Relationships between Remote Sensing, Cartography and Geographical Information System on a background of a physical, biological and social sciences

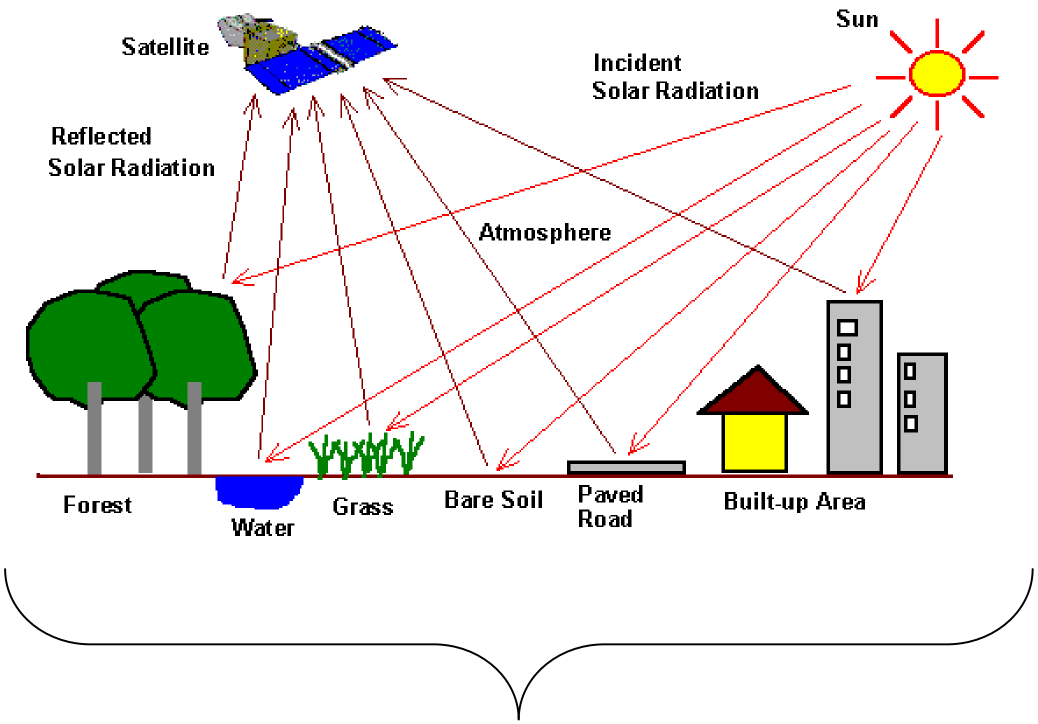


Remote Sensing - introduction

Why remote sensing is also an art?

- The ability of visual photo or digital image interpretation derives not only from scientific knowledge, but also from the experience acquired during a past life.
- Some image analyst are much superior to other image analysts because they:
  - Understand the scientific principles better,
  - are more widely travelled and have seen many landscape objects and geographic areas first-hand
  - can synthetize scientific principles and real-world knoowledge to reach logical and correct conclusions.

Remote Sensing - introduction



Radar has its own source of radiation.

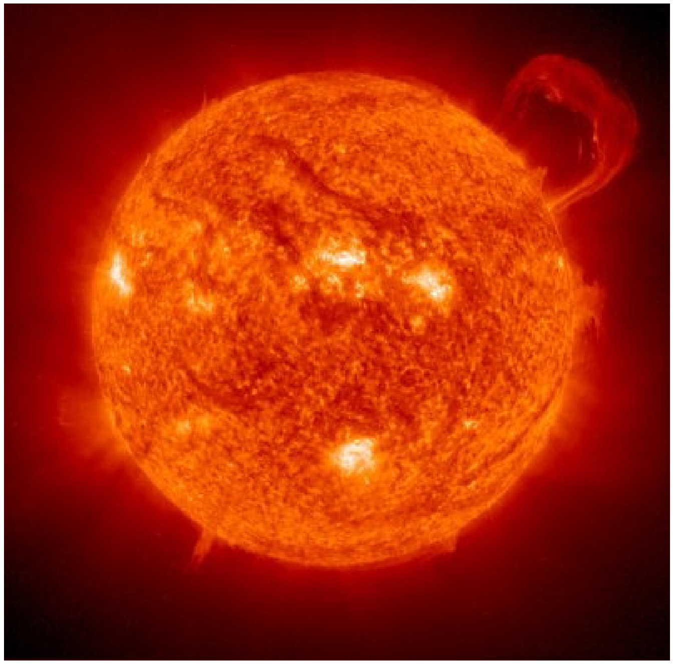
Output data:
- images-photography
- maps
- graphs
- digital numbers.

Incident solar radiation can be:

reflected, transsmitted and/or absorbed in various proportions depending on material characteristics

Remote Sensing - introduction

Solar energy – is created in the process of thermosynthesis - in which, by a combination of four protons in the nucleus of helium, the mass conversion into energy occurs.



Energy is the ability to do work
Can be transferred in:
conduction, convection and radiation

Radiation - transfer of energy that do not require physical contact between the body and absorbing radiant energy. Energetic particles or energetic waves travel through a medium or space. They ***radiate*** (i.e., travel outward in all directions) from a source.

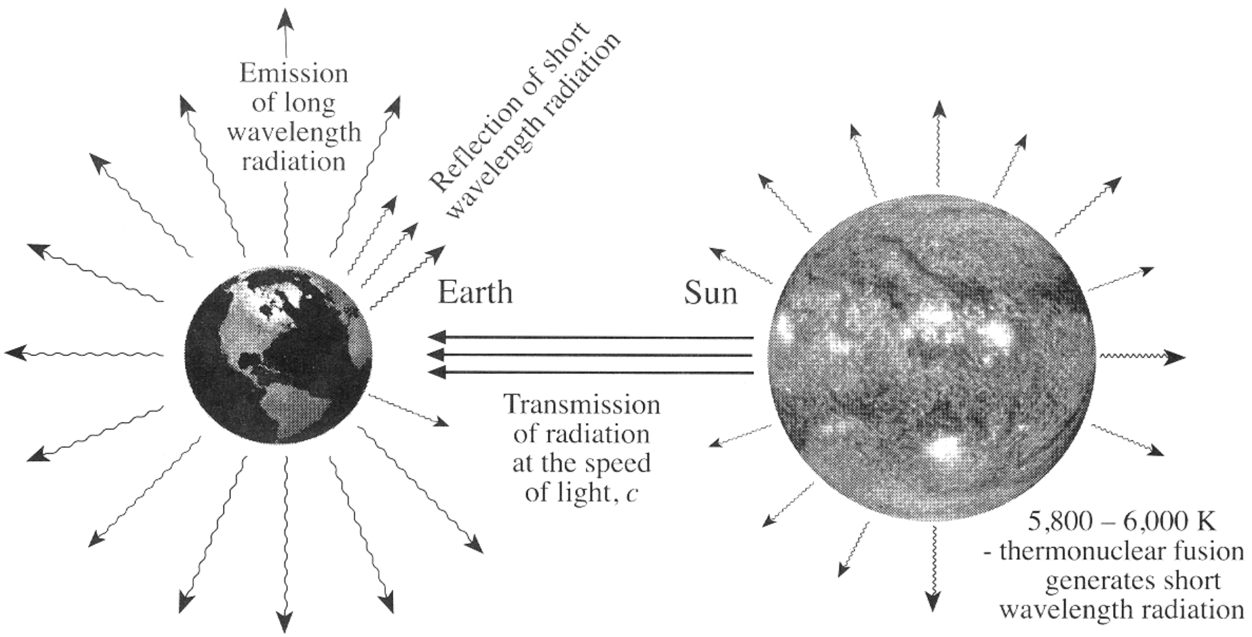
Radiation:

- ionizing (or ionising) radiation is radiation composed of particles that individually carry enough kinetic energy to liberate an electron from an atom or molecule, ionizing it. Ionizing radiation is generated through nuclear reactions, either artificial or natural, by very high temperature

- **non-ionizing**: the light from the Sun that reaches the earth is largely composed of non-ionizing radiation. Far-ultraviolet rays have been filtered out by the gases in the atmosphere, particularly oxygen.

Remote Sensing – electromagnetic radiation

Wave model – James C. Maxwell

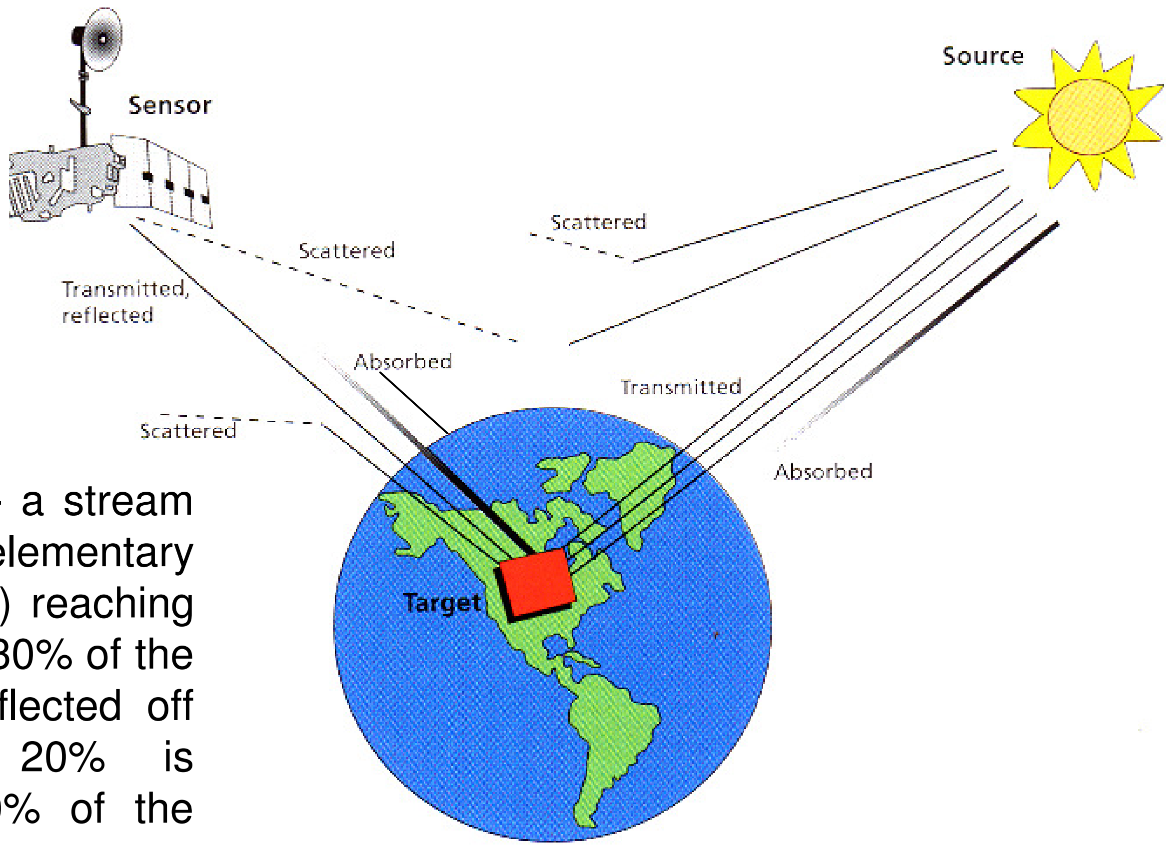


Blackbody – a theoretical construct that absorbs and radiates energy at the maximum possible rate per unit area at each wavelength for a given temperature

Stefan-Boltzmann law – the total emitted radiation from a blackbody [W m^{-2}] is proportional to the fourth power of its absolute temperature.

$$M_\lambda = \sigma T^4$$

TELEDETEKCJA podstawy fizyczne



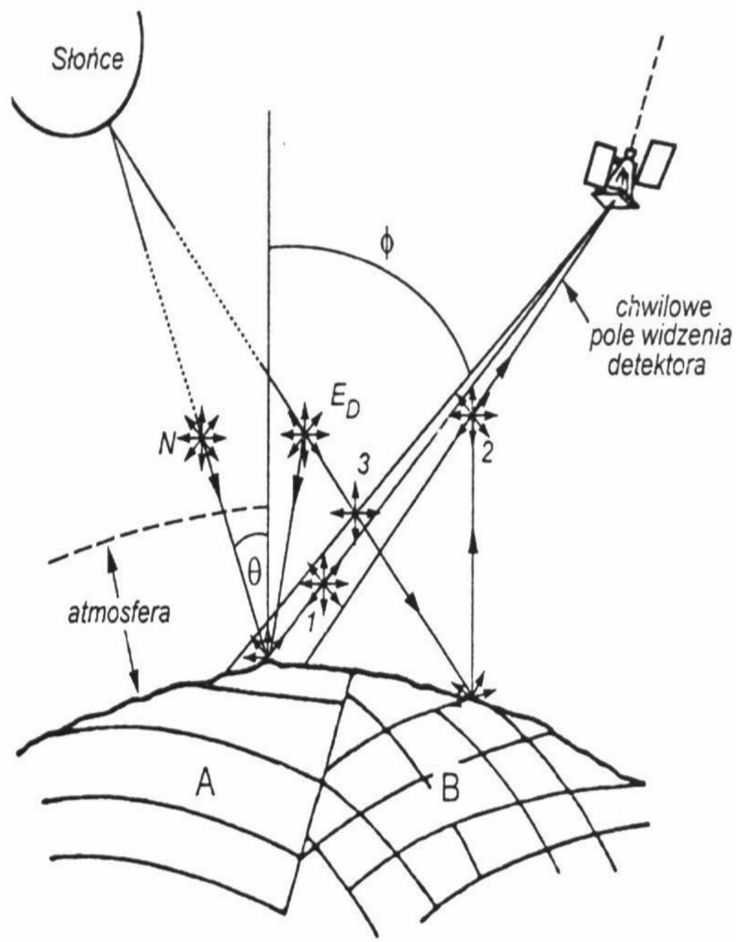
Solar radiation - Solar radiation - a stream of electromagnetic waves and elementary particles (corpuscular radiation) reaching the Earth from the Sun. About 30% of the incoming solar radiation is reflected off the planet's atmosphere, 20% is absorbed by it, and only 50% of the energy reach the Earth's surface.

Solar radiation:
- direct,
- diffuse (sky radiation) solar radiation from the hemisphere of the sky reaching the Earth's surface, with the exception of direct radiation,
- total.

Remote Sensing – electromagnetic radiation

The energy from the Sun being remotely sensed:

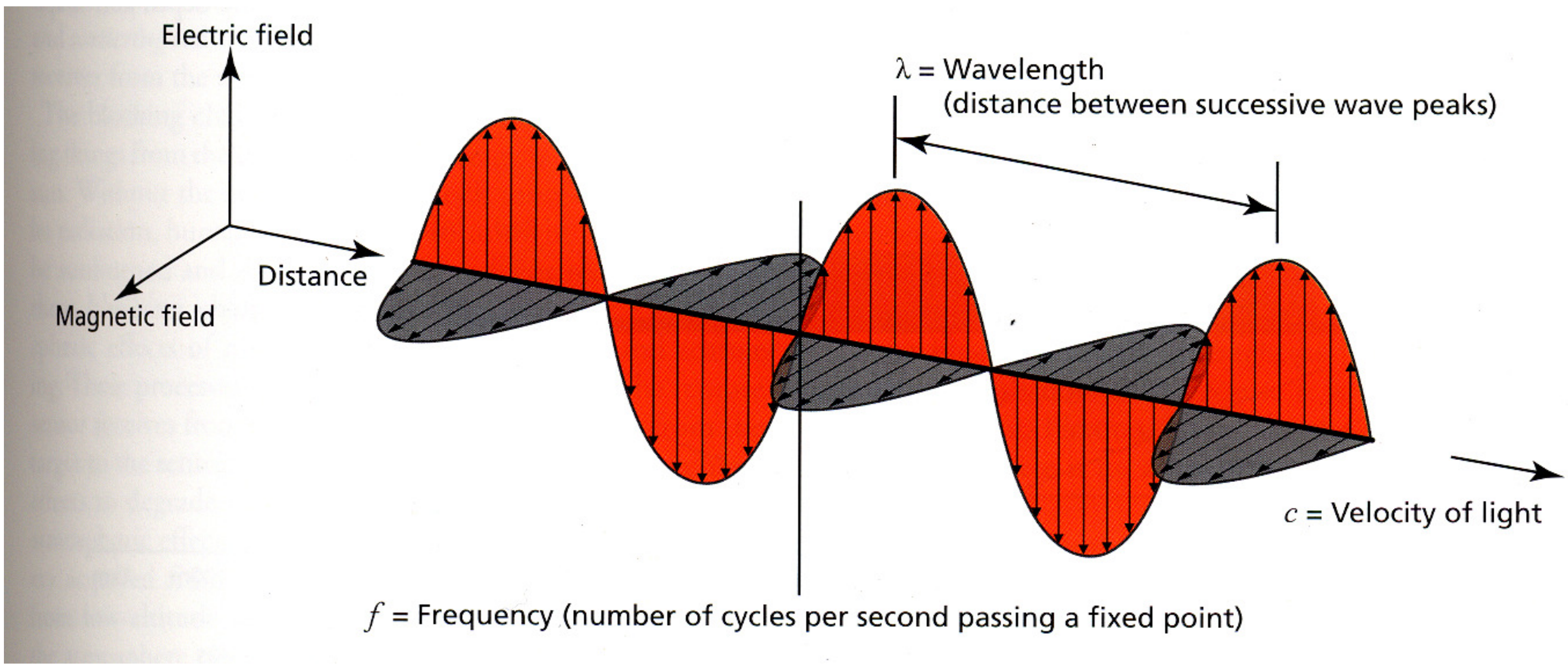
- is radiated by atomic particles at the source (the Sun),
- propagates through the vacuum of space at the speed of light,
- interacts with the Earth's atmosphere,
- interacts with the Earth's **surface**,
- interacts with the Earth's atmosphere once again, and
- finally reaches the remote sensing, where it interacts with various optical systems, filters, film emulsions, or detectors.



Remote Sensing – electromagnetic radiation

Wave model – James C. Maxwell

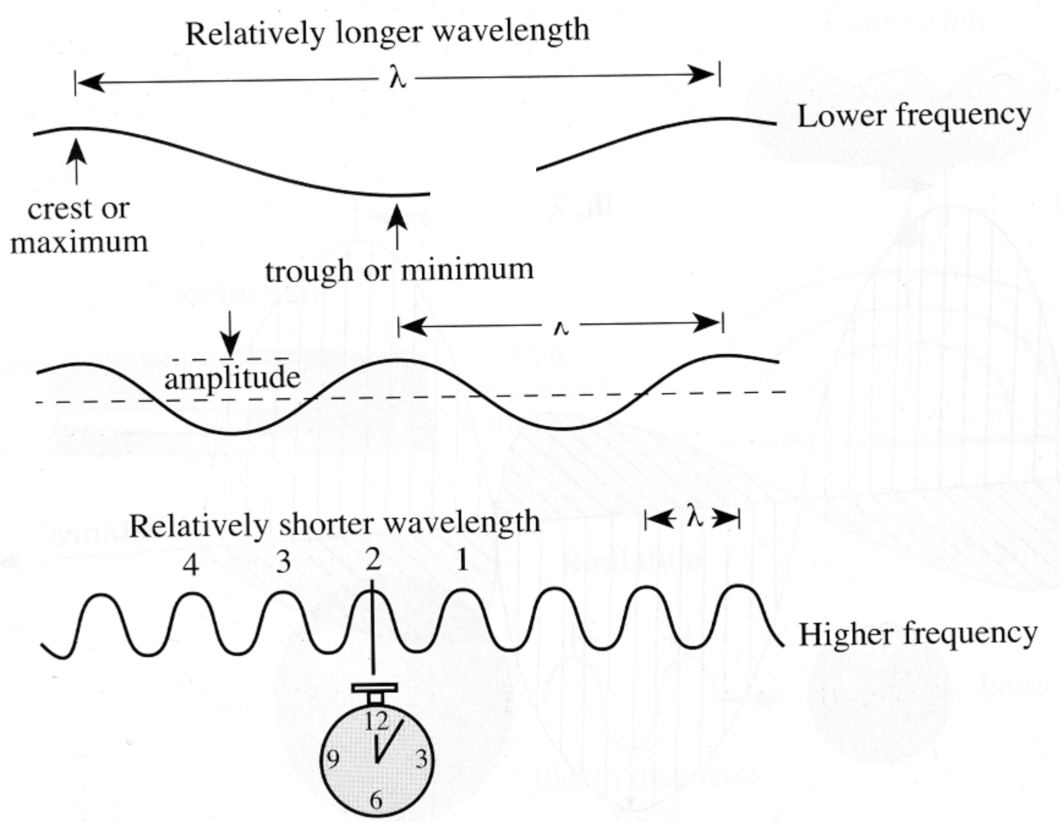
An electromagnetic wave is composed of both electric and magnetic vectors that are orthonogal (at 90° angles) to one another



The waves travel from the source at the speed of light (3×10^8 m s^{-1})

Remote Sensing – electromagnetic radiation

Wave model – James C. Maxwell



Wavelength - the mean distance between maximums (or minimums) of a roughly periodic pattern [μm or nm].

Frequency - the number of wavelengths that pass a point per unit time [Hz].

$$c = \lambda v \qquad v = c/\lambda \qquad \lambda = c/v$$

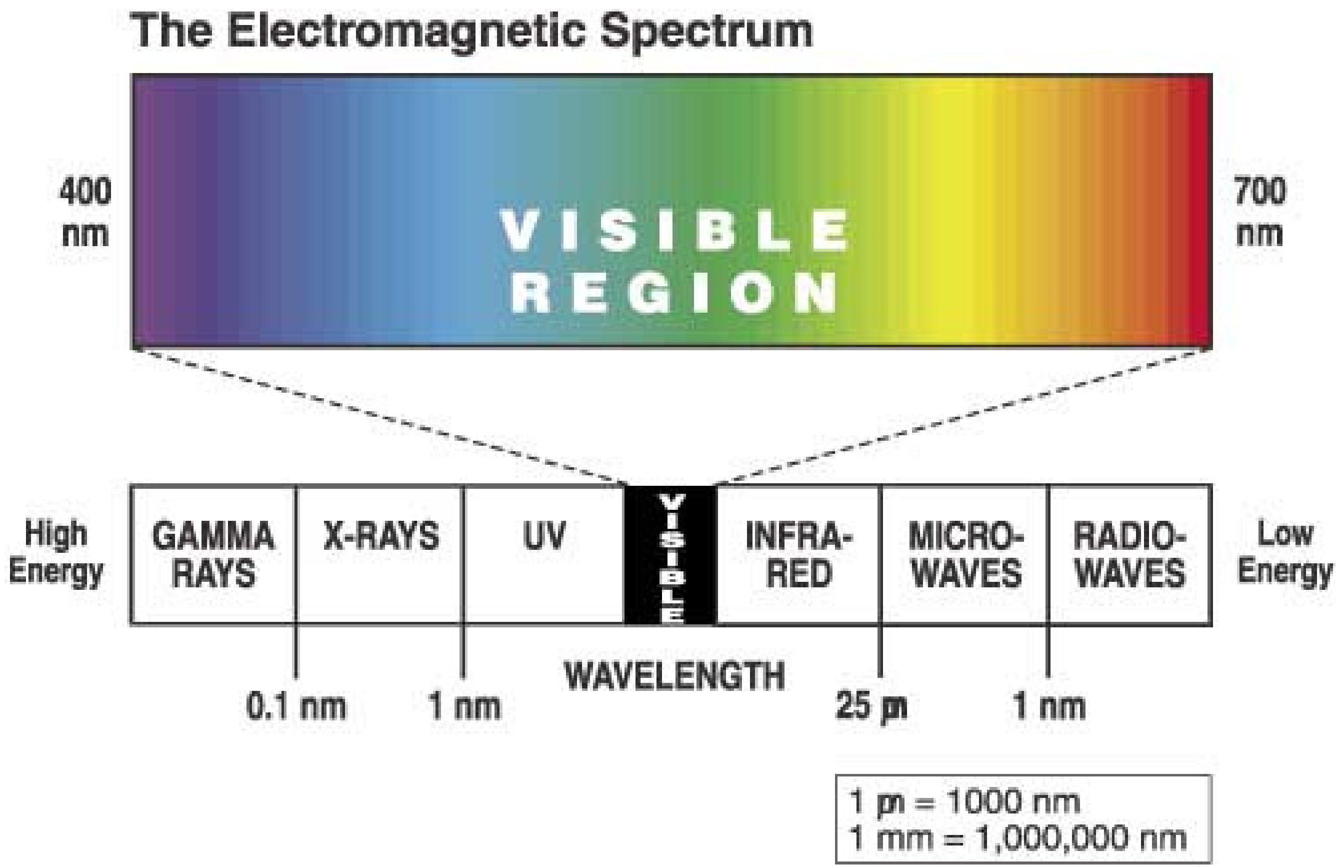
c – speed of light,
λ – wavelength,
v – frequency.

The longer the wavelength, the lower the frequency;

the shorter the wavelength, the higher the frequency.

[Jensen 2000]

Remote Sensing – electromagnetic radiation



Blue: 400–500 nm

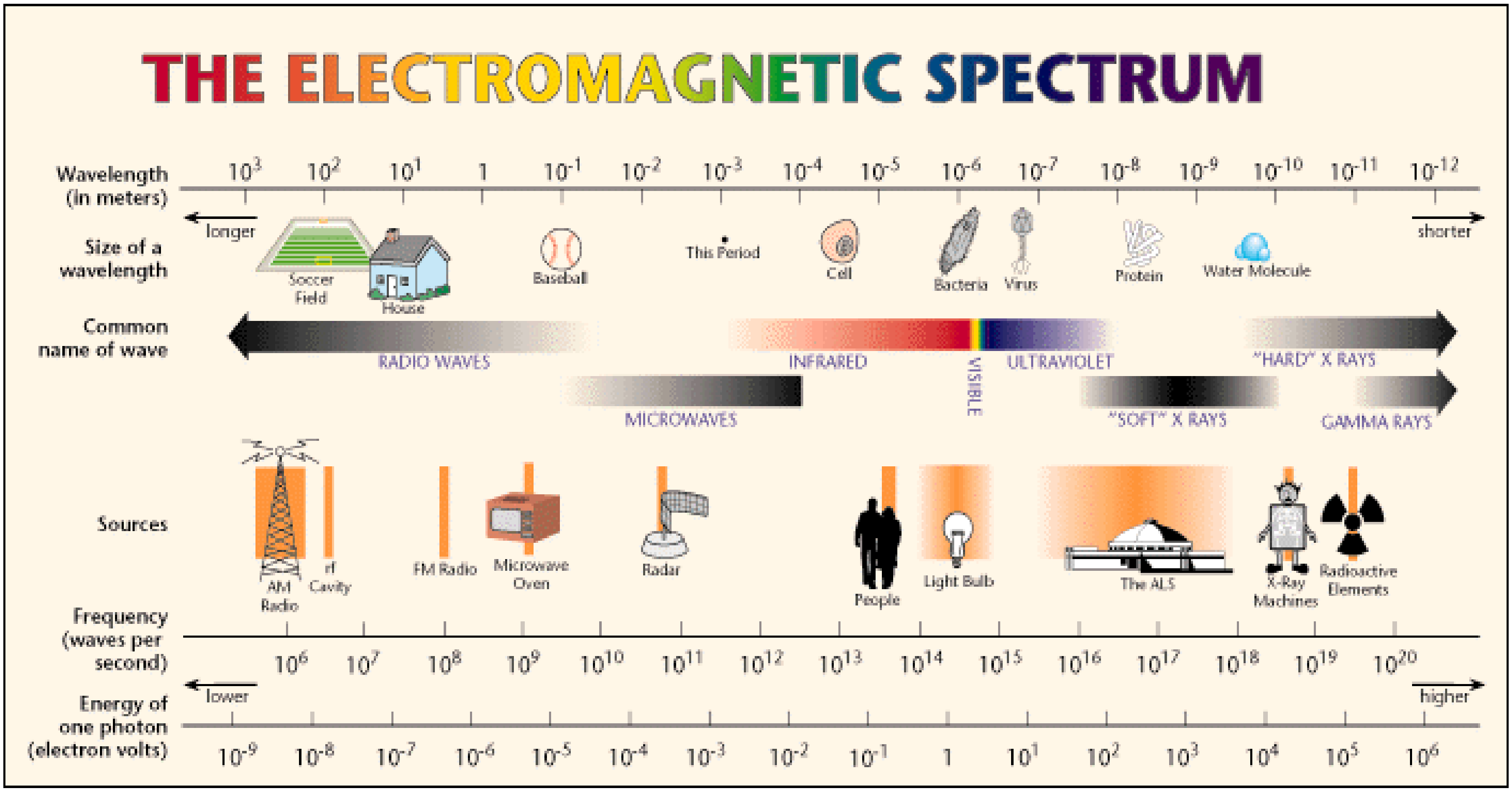
Green: 500-600 nm

Red: 600-700 nm

Optical remote sensing: visible + infrared

Infrared - near infrared (700-1300 nm) + short-waveinfrared (1300 – 2500 nm)

Remote Sensing – electromagnetic radiation



Remote Sensing – electromagnetic radiation

Visible wavelength

Near-infrared wavelength

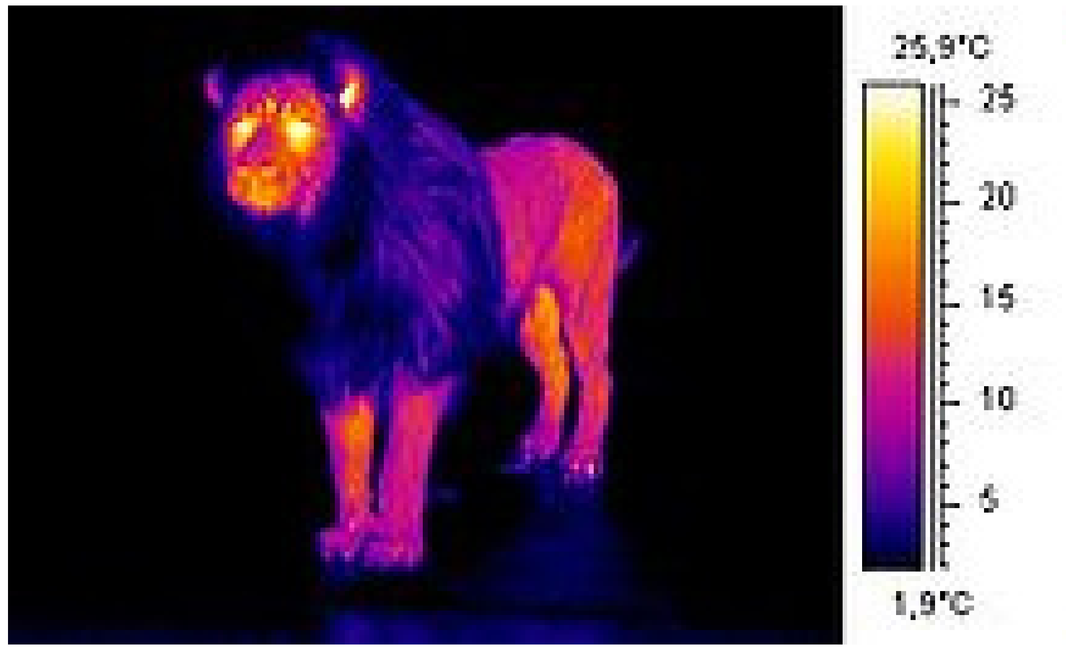


Photo of a lion taken in the mid-infrared
(colors contractual)

Remote Sensing – electromagnetic radiation

Himalyan balsam (policeman's helmet) - *Impatiens glandulifera*

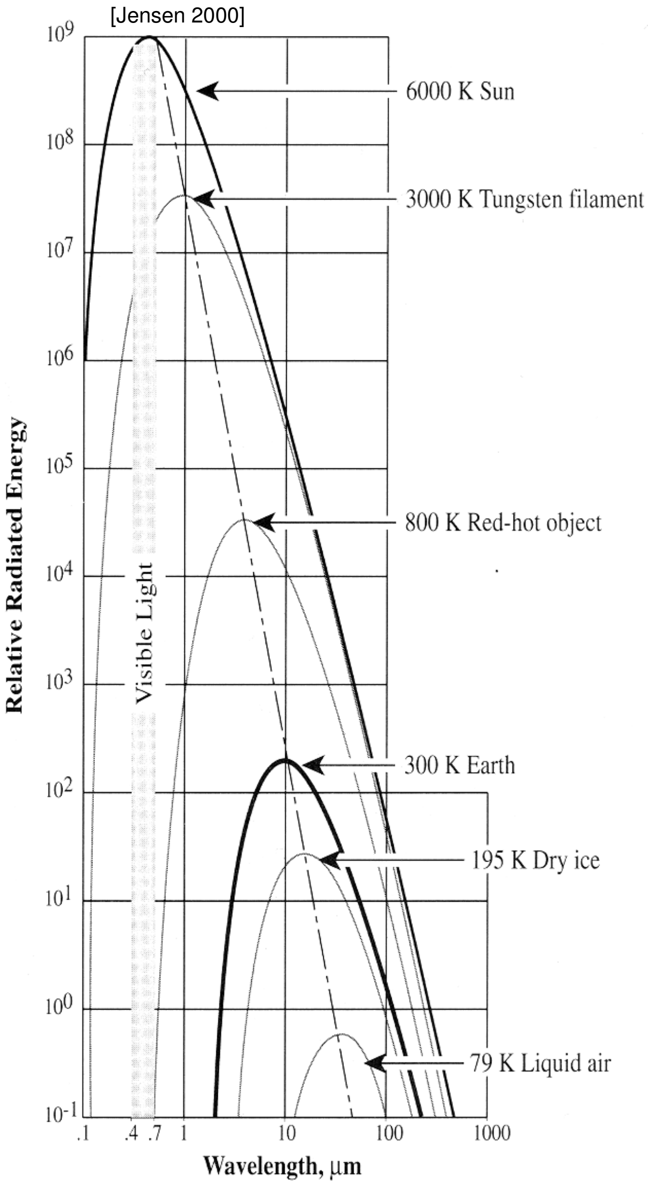
Human Vision

Bee Vision Simulation

Butterfly Vision Simulation

[The World as Seen By Butterflies]

Remote Sensing – electromagnetic radiation



Blackbody radiation curves

Wave model – James C. Maxwell

Wiens displacement law

(dominant wavelength)

$$\lambda_{max} = k/T$$

k – a constant equaling 2898 µm K
T – absolute temp. in degrees K

Remote Sensing – electromagnetic radiation

The particle model

Photon energy units:

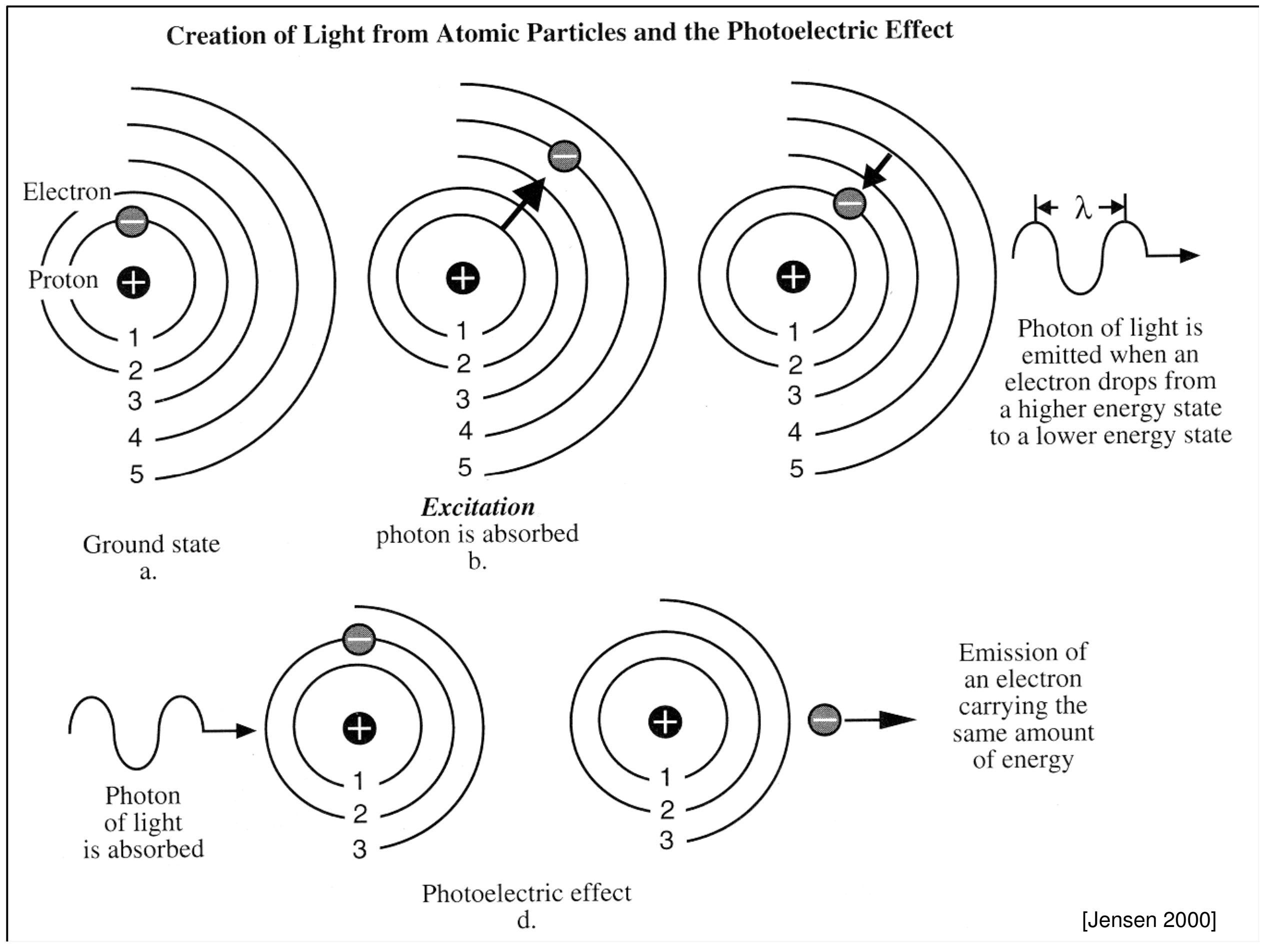
Joules (J)

electron volts (eV)

$$Q = hv$$

Q - the energy of a quantum measured in Joules (J),
h - the Planck constant (6.626×10^{-34} J s),
v - the frequency of the radiation,
c – speed of light.

$$\lambda = \frac{hc}{Q} \quad \text{or} \quad Q = \frac{hc}{\lambda}$$



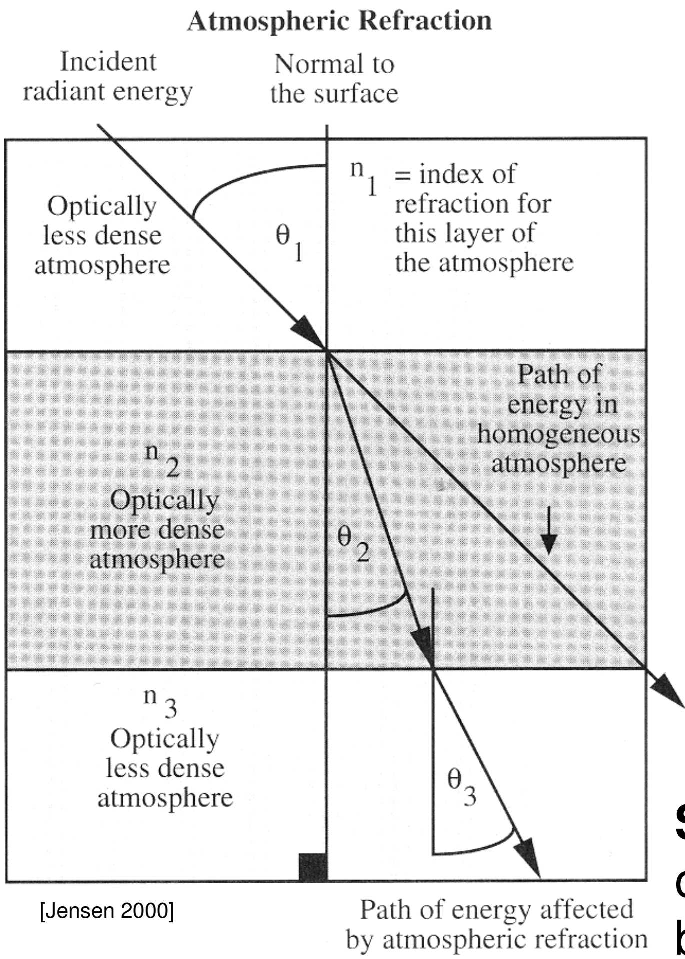
Remote Sensing – electromagnetic radiation

Radiant energy (*Q*)

- Electromagnetic radiation can be described using both wavelength λ, frequency ν and size of radiant energy Q, which causes photochemical reaction in the emulsion film or inducing light-sensitive element (eg CCD).
- Radiant energy Q is understood as the ability of radiation to perform physical work, warm-up or cause changes in state of matter, measured in J or eV.

Remote Sensing – electromagnetic radiation

Energy – Matter interaction in the Atmosphere



[Jensen 2000]

Radiant energy - the capacity of radiation within a spectral band to do work

Refraction - the bending of light when it passes from one medium to another

Index of refraction - measure of the optical density of a substance.
Atmosphere - 1.0002926
Water - 1.33

$$n = \frac{c}{c_n}$$

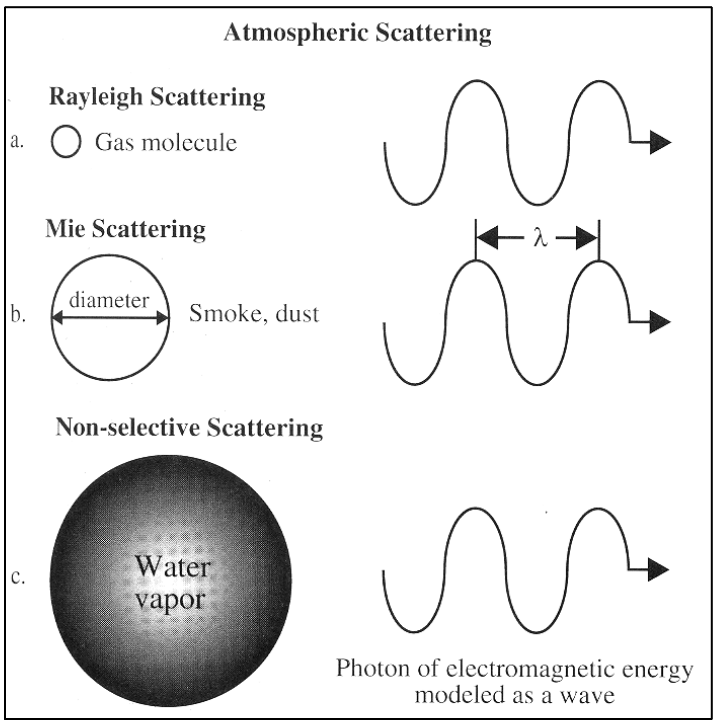
where: c – speed of light in a vacuum,
c_n – speed of light in a given substance.

Snell's law - for a given frequency of light the product of the index of refraction and the sine of the angle between the ray and a line normal to the interface is constant

Remote Sensing – electromagnetic radiation

Energy – Matter interaction in the Atmosphere

__Scattering__ *is a general physical process where some forms of radiation, such as light are forced to deviate from a straight trajectory by one or more localized non-uniformities in the medium through which they pass.*
The direction associated with scattering is unpredictable.
The direction of **reflection** is **predictable**



[Jensen 2000]

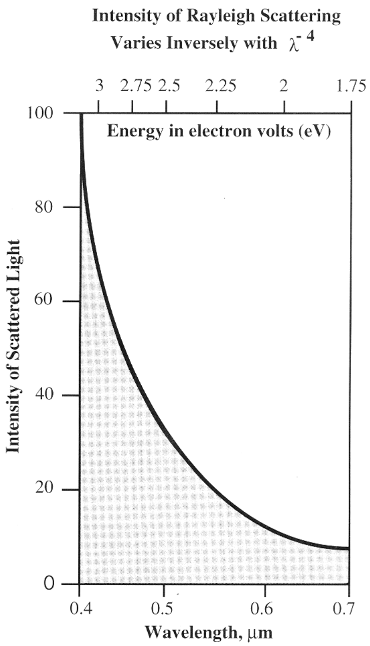
Rayleigh scattering (molecular scattering) – at particles with the effective diameter many times smaller (usually < 0.1) than the wavelength of the incident electromagnetic radiation

UV light at 300 nm is scattered approximately 16 times more than red light at 600 nm

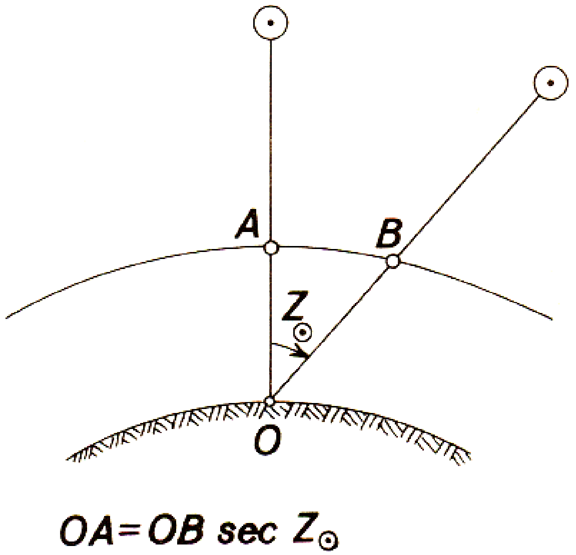
Blue light at 400 um is scattered about 5 times that of red light at 600 nm

Remote Sensing – electromagnetic radiation

Energy – Matter interaction in the Atmosphere



Rayleigh scattering



Remote Sensing – electromagnetic radiation

Energy – Matter interaction in the Atmosphere

Mie scattering (nonmolecular scattering) – at particles with diameters approximately equal to the size of the wavelength of the incident energy

Number of dust particles in 1 cm^3 over:

Ocean	70 -340
High mountains	400 – 8 000
Arable fields after rain	32 000
Arable fields during sunny days	130 000
Urban areas	170 – 470 000

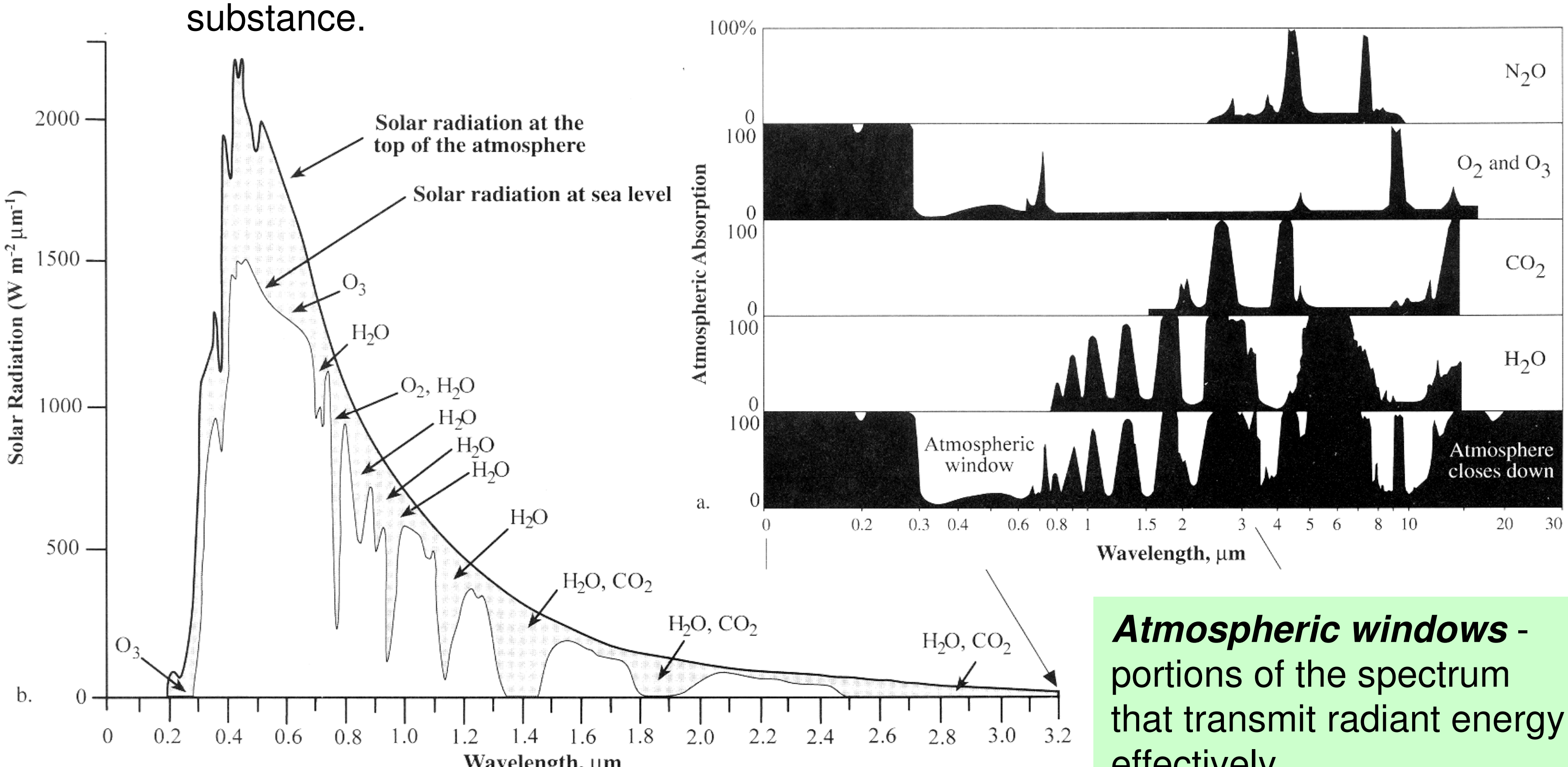
Non-selective scattering takes place in the lowest portions of the atmosphere where there are particles greater than 10 times the wavelength of the incident electromagnetic radiation

Remote Sensing – electromagnetic radiation

Energy – Matter interaction in the Atmosphere

Absorption is the process by which radiant energy is absorbed and converted into other forms of energy.

An ***absorption band*** is a range of wavelengths (or frequencies) in the electromagnetic spectrum within which radiant energy is absorbed by a substance.

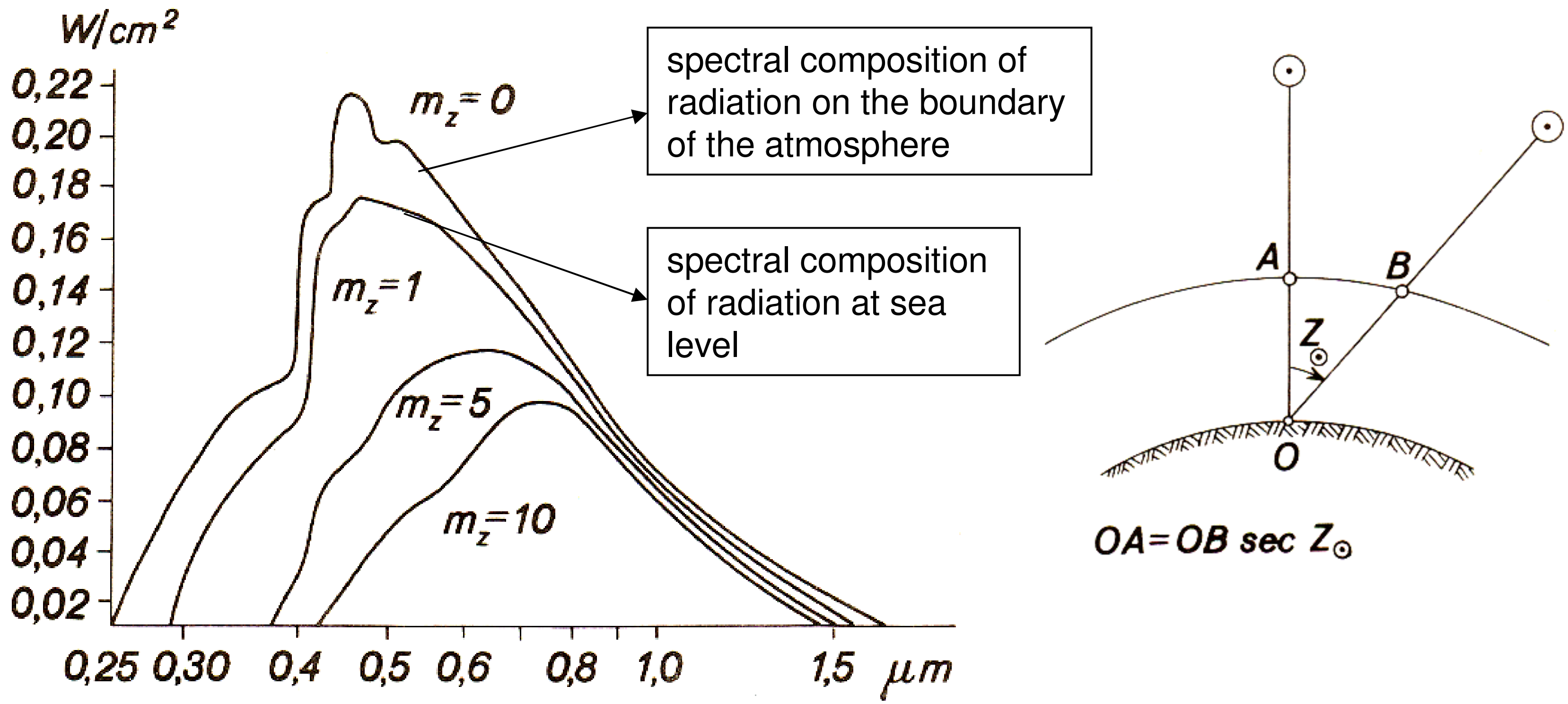


[Jensen 2000]

Atmospheric windows - portions of the spectrum that transmit radiant energy effectively.

Remote Sensing – electromagnetic radiation

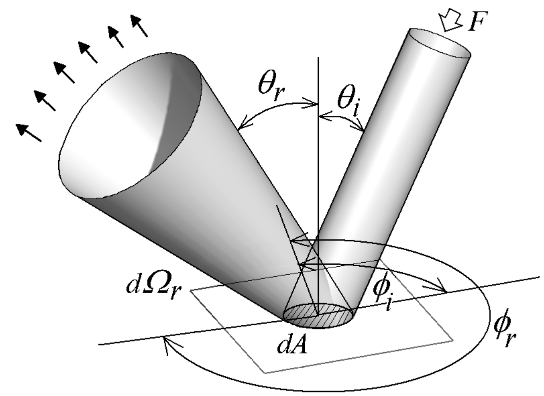
Energy – Matter interaction in the Atmosphere



The spectral composition and intensity of solar radiation depending on the thickness of the atmosphere, through which the radiation passes (A.S. Kuczko) [Wójcik]

Remote Sensing – electromagnetic radiation

Radiant flux - the amount of radiant energy onto, off of, or through a surface per unit time and is measured in Watts (W).



Radiation budget equation:

$$\Phi_{i_\lambda} = r_\lambda + \tau_\lambda + \alpha_\lambda$$

Hemispherical reflectance - the ratio of the radiant flux reflected from a surface to the radiant flux incident to it (dimensionless).

Reflectance factor: $\rho_{r_\lambda} = \frac{\Phi_{reflected}}{\Phi_{i_\lambda}} \bullet 100$

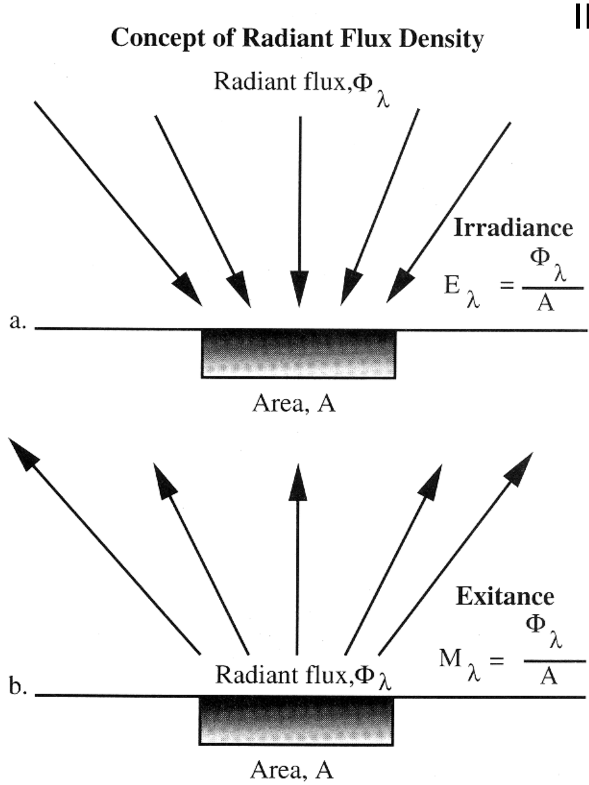
Hemispherical transmittance - the ratio of the radiant flux transmitted through a surface to the radiant flux incident to it (dimensionless)

Hemispherical absorptance - the ratio of the radiant flux absorbed by a surface to the radiant flux incident to it (dimensionless)

Hemisphere – half of the sphere

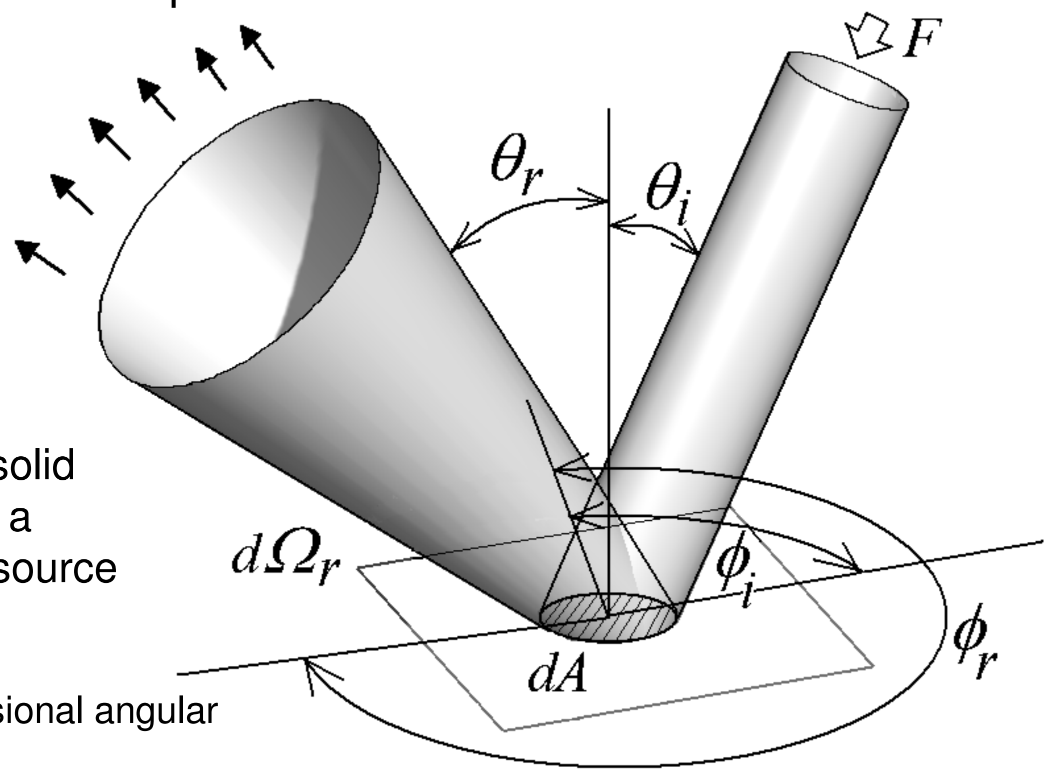
Remote Sensing – electromagnetic radiation

Radiant Flux Density - the amount of radiant flux intercepted divided by the area of the plane surface.



Irradiance - the amount of radiant flux incident per unit area of a plane surface.

Exitance - the amount of radiant flux leaving per unit area of the plane surface.

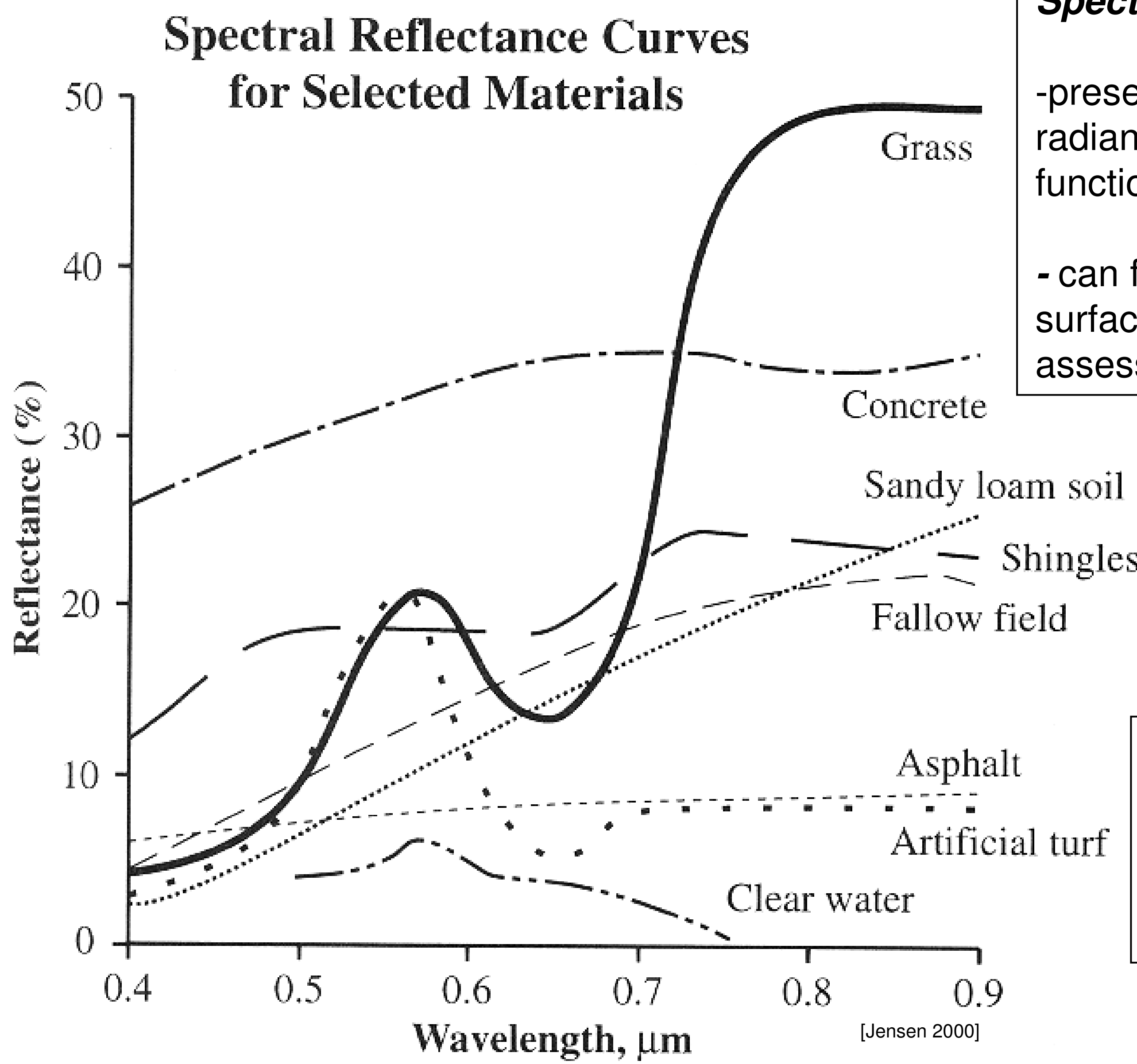


Radiance - the radiant flux per unit solid angle leaving an extended source in a given direction per unit of projected source area in that direction [$W*m^{-2}*sr^{-1}$].

Steradian is used to describe two-dimensional angular spans in three-dimensional space.

[Jensen 2000]

Remote Sensing – electromagnetic radiation



Spectral reflectance curves:

-present amount of reflected radiance as reflectance in the function of wavelength,

- can form the basis for object or surface identification and assessment.

spectral reflectance curves diagram - p*resents amount of reflected radiance as reflectance in the function of wavelength*

Remote Sensing – electromagnetic radiation

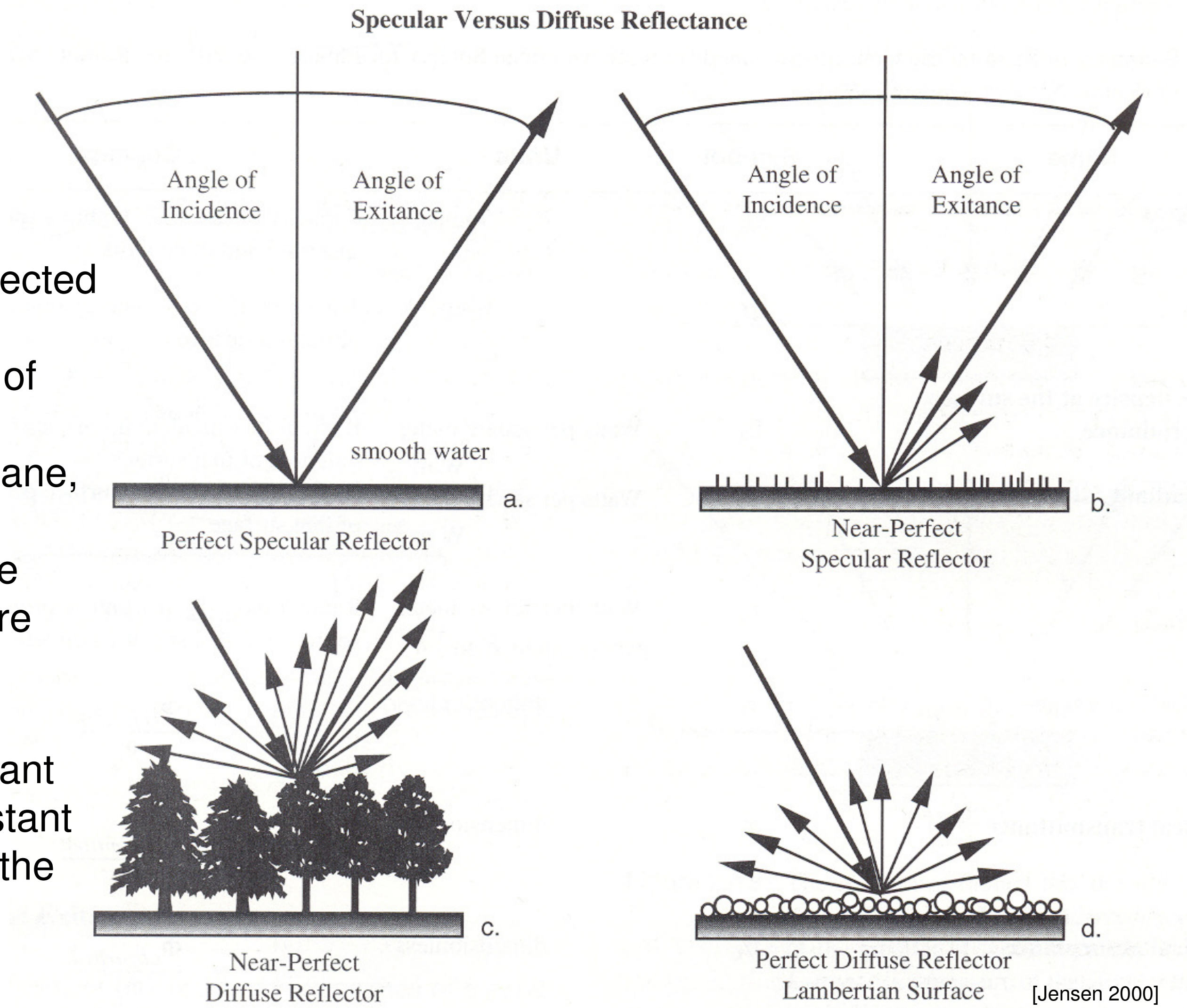
Reflectivity and reflectance refer to the fraction of incident electromagnetic power that is reflected at an interface

Reflection - fundamental characteristics ***:***

- the incident radiation, the reflected radiation, and a vertical to the surface from which the angles of incidence and reflection are measured all lie in the same plane,

- the angle of incidence and the angle of reflection (exitance) are approximately equal.

Lambertian surface - the radiant flux leaving the surface is constant for any angle of reflectance to the surface



[Jensen 2000]

Remote Sensing – electromagnetic radiation

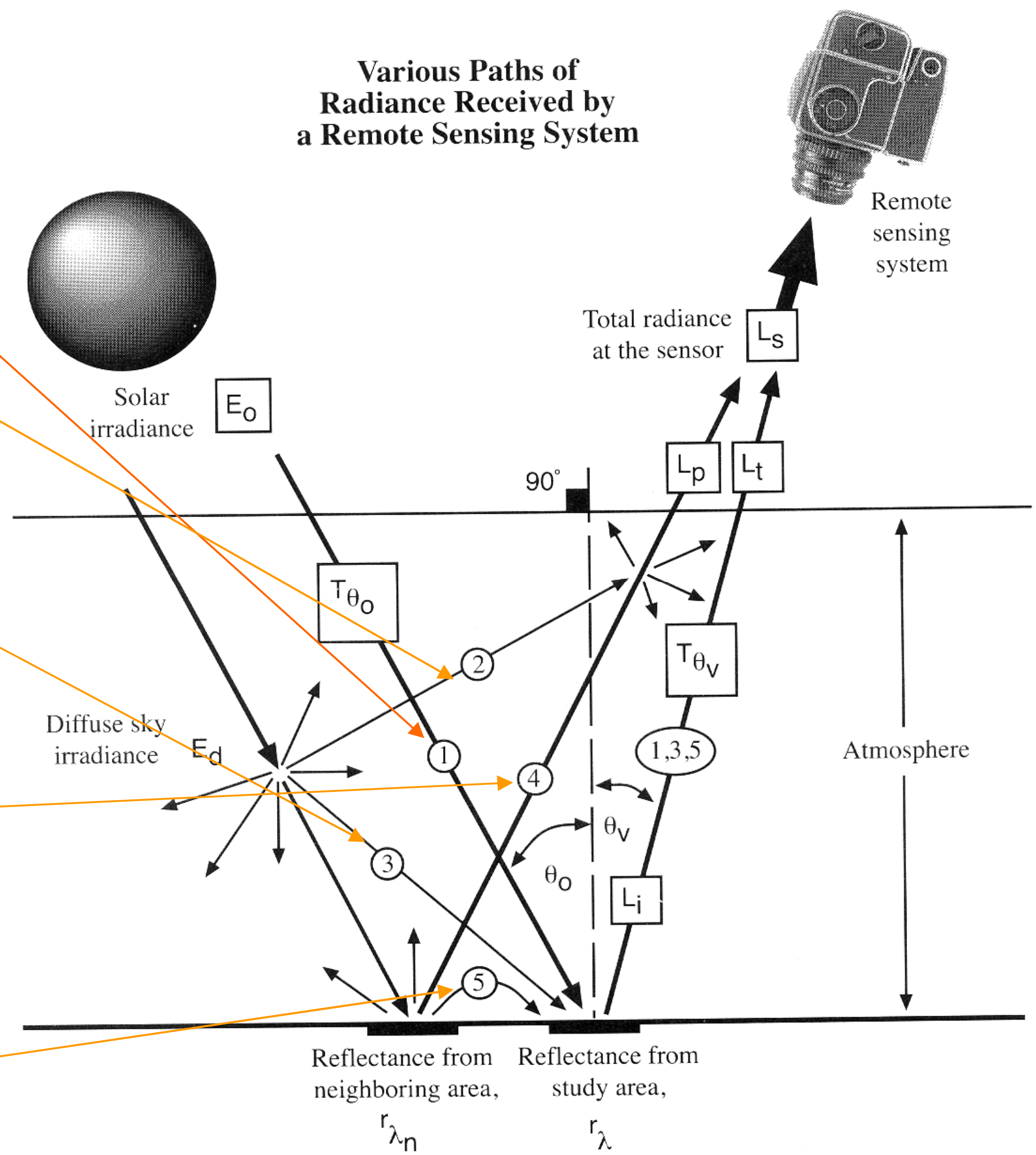
Path 1 - contains spectral solar irradiance (*E*o) that was attenuated very little before illuminating the terrain within the IFOV.

Path 2 contains spectral diffuse sky irradiance (*Ed*) that never even reaches the Earth's surface (the study area) because of scattering in the atmosphere.

Path 3 contains energy from the Sun that has undergone some scattering, absorption and reemission before illuminating the study area

Path 4 contains radiation that was reflected or scattered by nearby terrain (rA) covered by snow, concrete, soil, water, and/or vegetation into the IFOV of the sensor system.

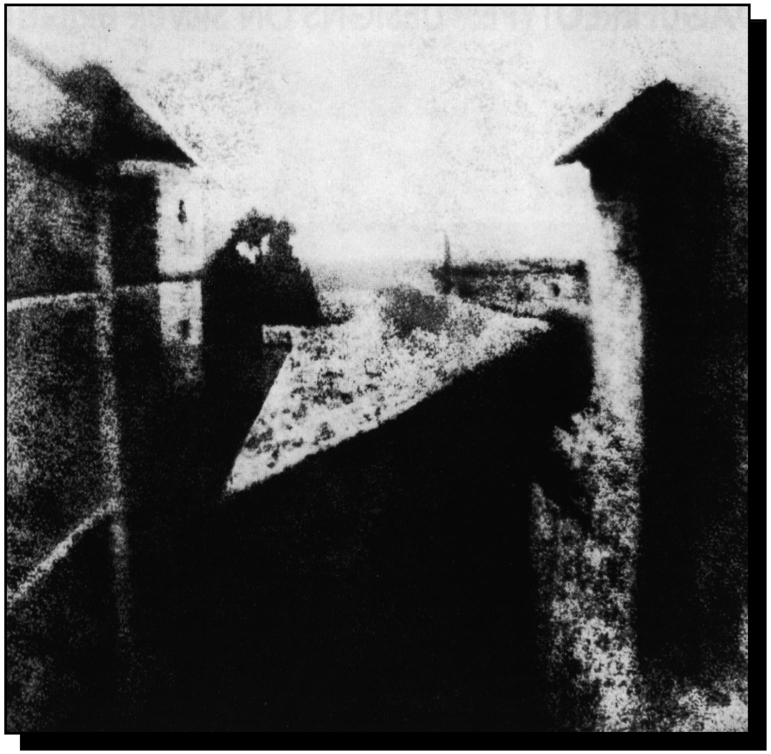
Path 5 is energy that was also reflected from nearby terrain into the atmosphere, but then scattered or reflected onto the study area.



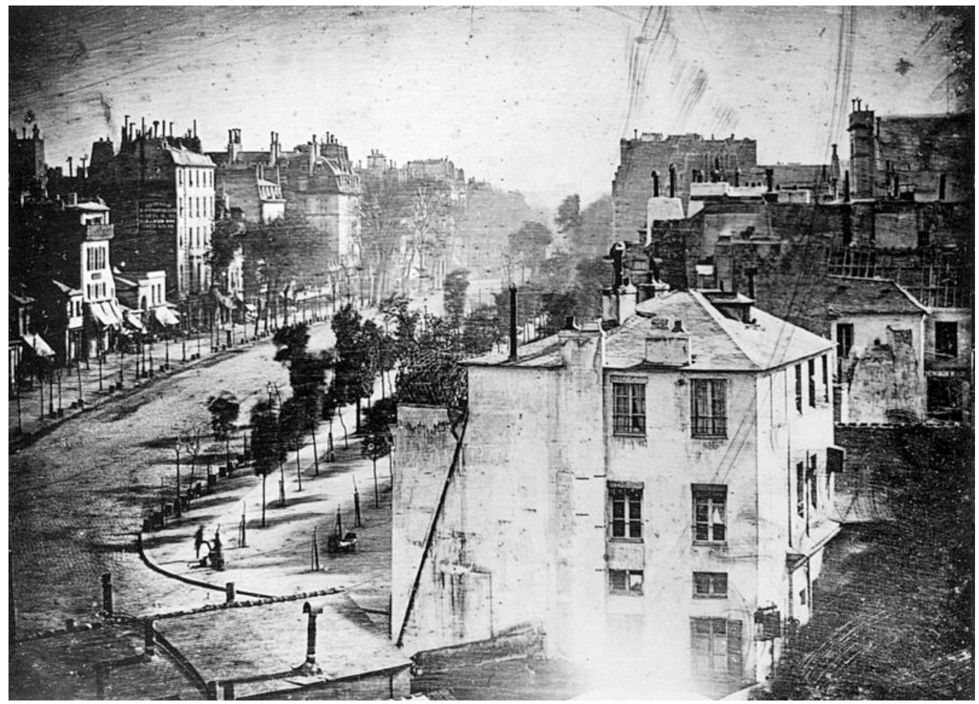
[Jensen 2000]

Remote Sensing – history

-Metal plate.
-White bitumen of Judea (derivative of petroleum) which hardens with exposure of light.
-Silver compounds (silver nitrate $AgNO_3$)

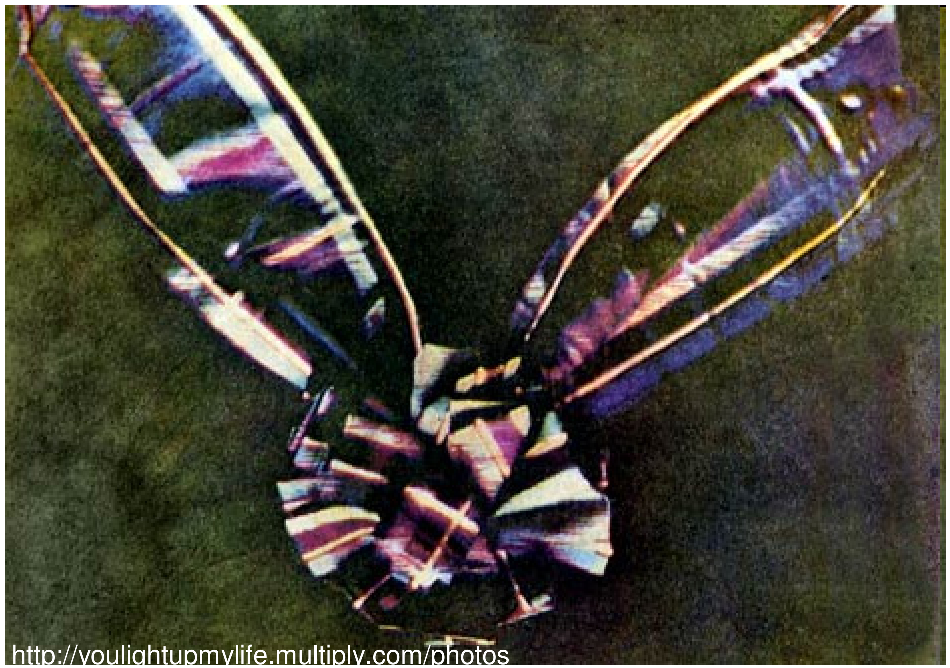


Nicephore Niepce's earliest surviving photograph of a scene from nature, circa 1826, „View from the window at Le Gras" Saint-Loup-de-Varennes (France).



"Boulevard du Temple", taken by Louis Daguerrein late 1838 or early 1839, was the first-ever photograph of people.

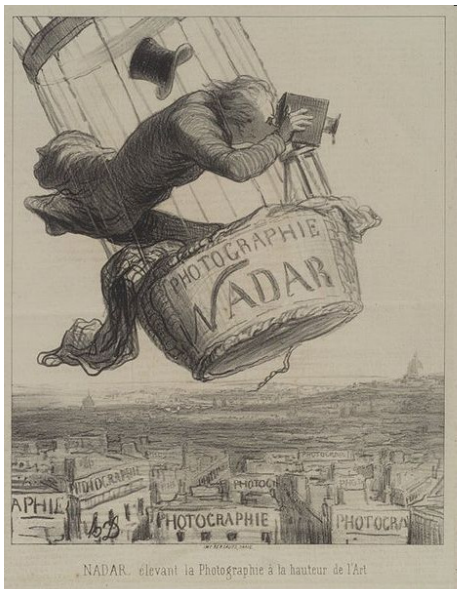
Remote Sensing – history



James Clerk Maxwell - First Color Photograph - 1861

Remote Sensing – history

Balloons



Gaspard Felix Tournachon (*Nadar*)
1858

The oldest surviving aerial photo of Boston in 1860, taken by James Wallace Black, from a balloon.

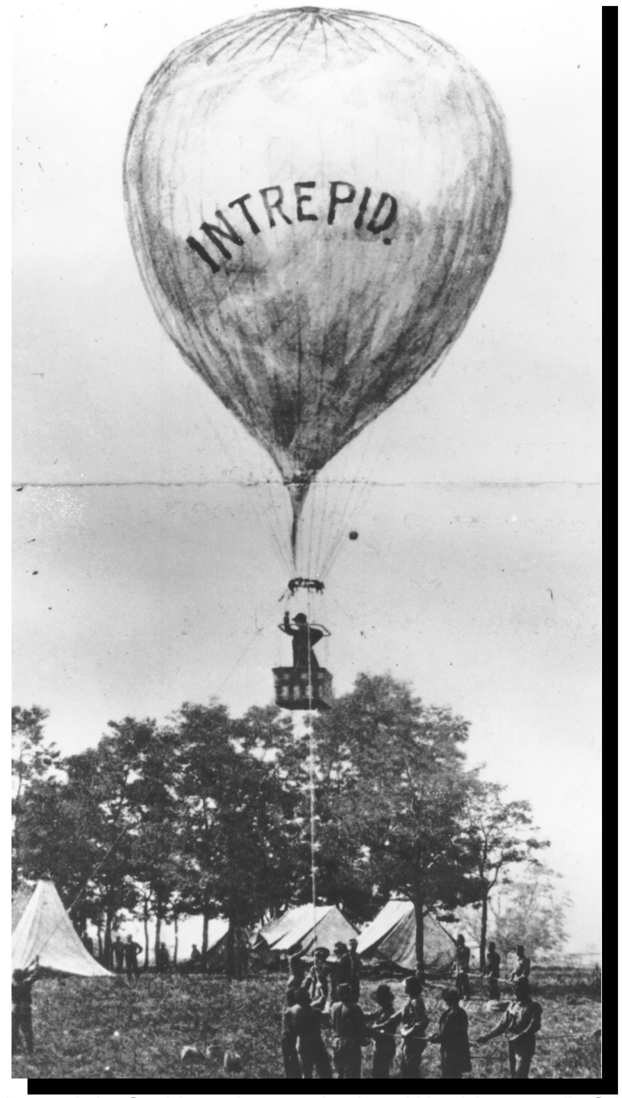
In 1858, Nadar applied for a patent for an „***aerial survey*** **-** *the mapping of the land from a series of overlapping aerial photographs* "

Remote Sensing – history

(copyright Smithsonian Institution, Washington, D.C.).

A portion of an aerial photograph of downtown Boston, MA. obtained by Black and King at altitude of 400 m. First aerial photograph taken from a captive ballon in the USA.

Balloons



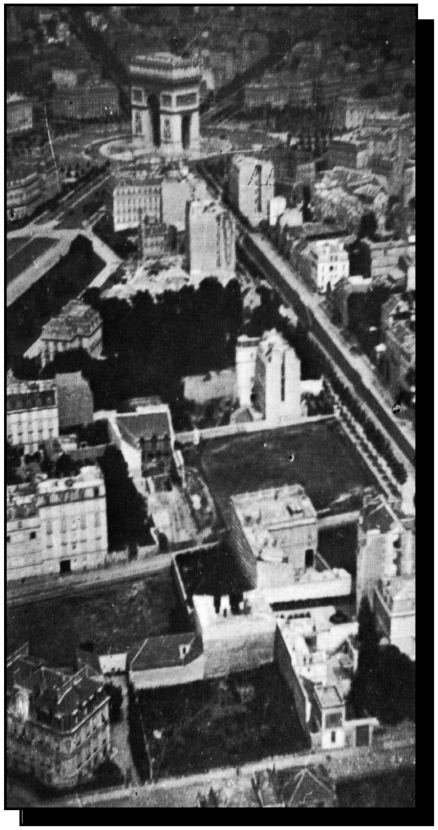
(copyright Smithsonian Institution, Washington, D.C.).

Balloon *Intrepid* tethered during the Civil War battle of Fair Oaks on June 1, 1862

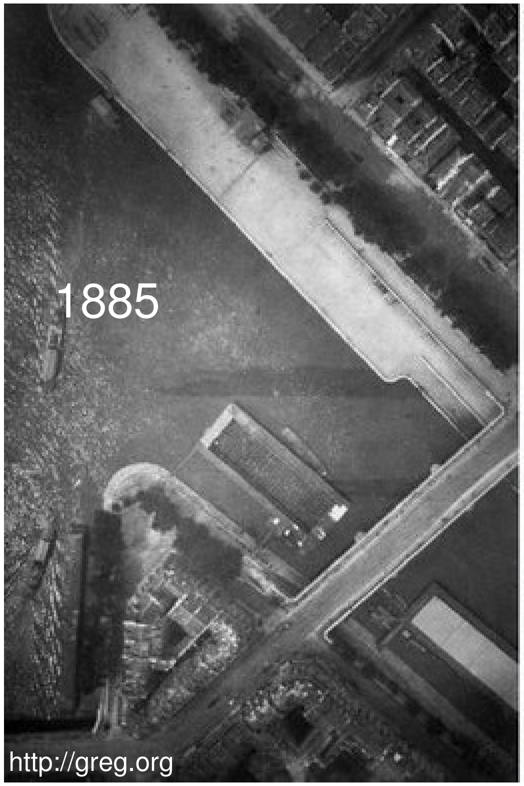
[Jensen 2000]

Remote Sensing – history

Balloons



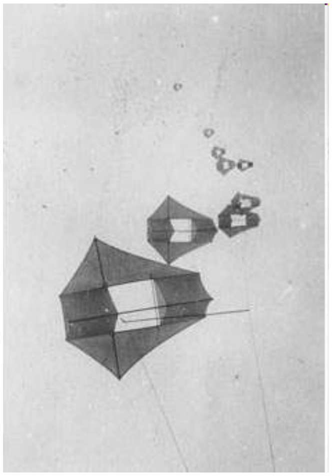
Oblique photograph obtained from the *Hippodrome* Balloon using a multiband camera (1868).
Nadar



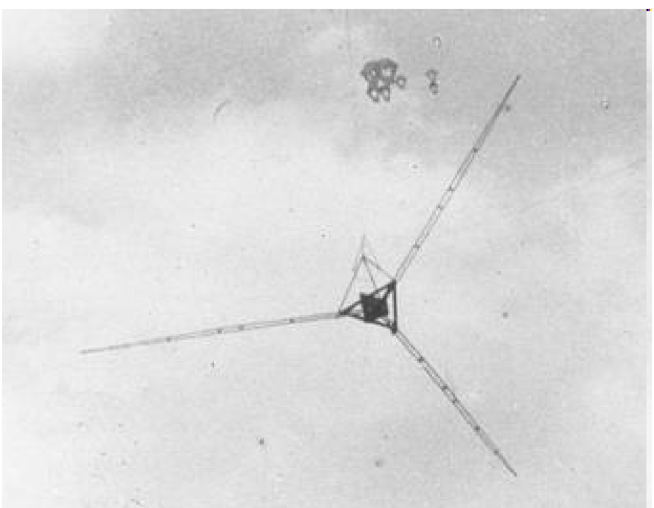
Paris, the pont Louis-Phillippe
Gaston Tissandier and Jacques Ducom (dry-plate process)

Remote Sensing – history

Kites



a train of nine Conyne kites



the kite train and camera-steadying mechanism 'Captive Airship."

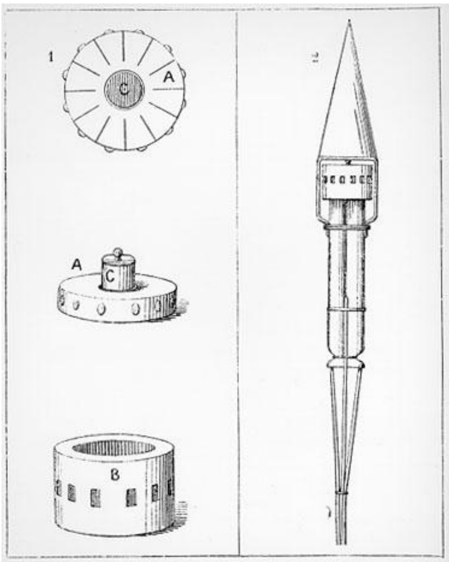
George Lawrence - *Captive Airship*

Six weeks after the April 18, 1906

1908

Remote Sensing – history

Rockets



"Photo rocket" conceived by the Frenchman Amedee Denisse in 1888

View of a village in Sweden thought to be taken by Alfred Nobel's photo rocket in 1897

German landscape photographed in 1904 by the camera system of Alfred Maul, a pioneer in photo rocketry.

http://www.nasm.si.edu

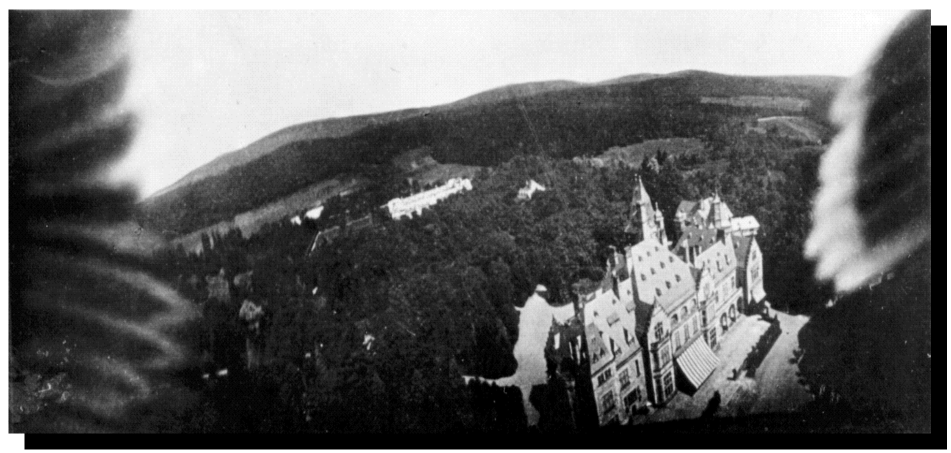
Remote Sensing – history

Pigeons

Deutsches Museum, Munich

Pigeon with miniature camera

Patented in 1903



Remote Sensing – history

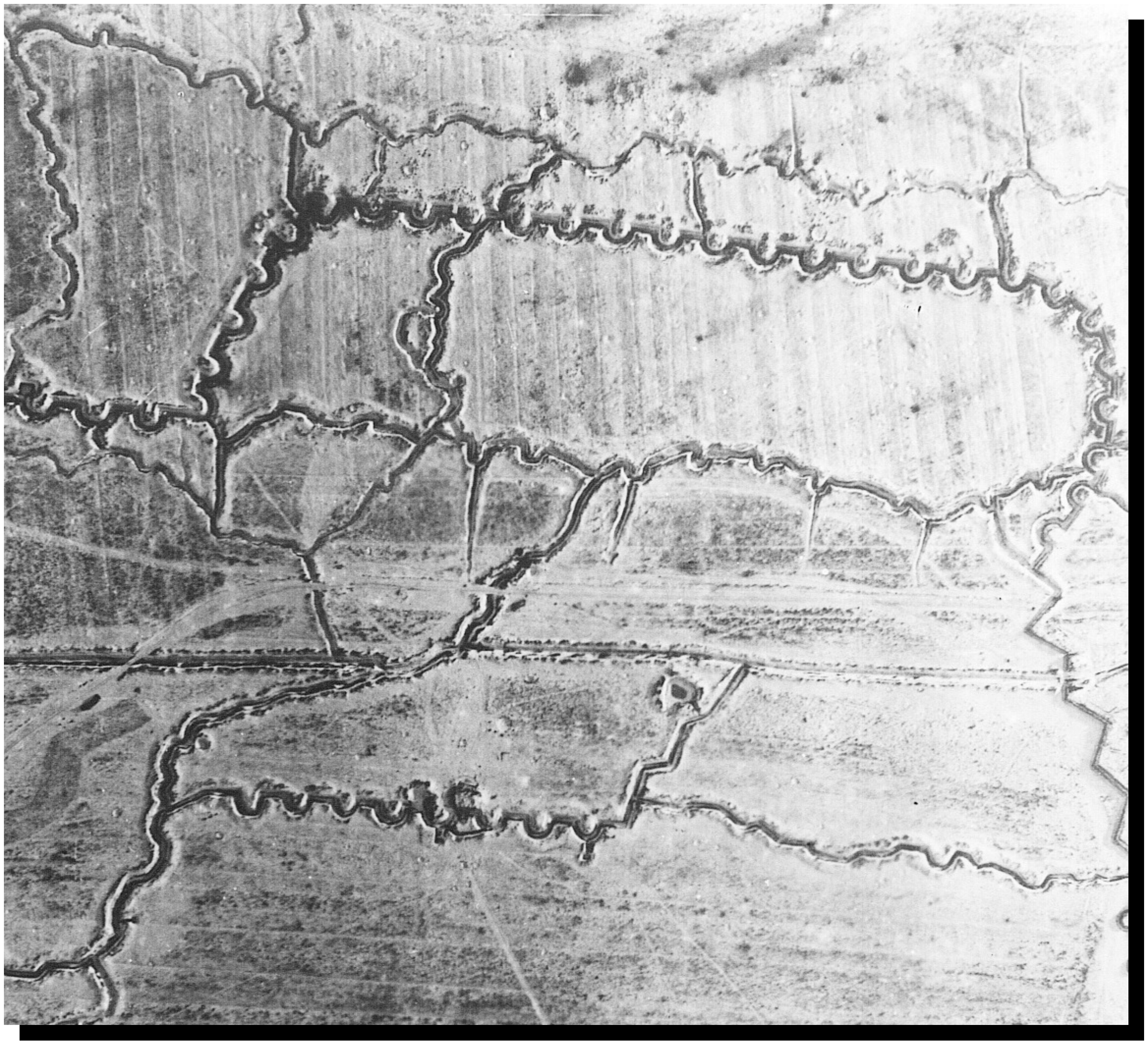
Aeroplanes

The Wright Flyer built by Orville and Wright. The first successful heavier-than-air engine-powered flight on December 1903

11 seconds and 40 meters

Remote Sensing – history

World War I



"a most disgraceful thing to have attempted"

Vertical photography of World War I trenches in Europe.

[Jensen 2000]

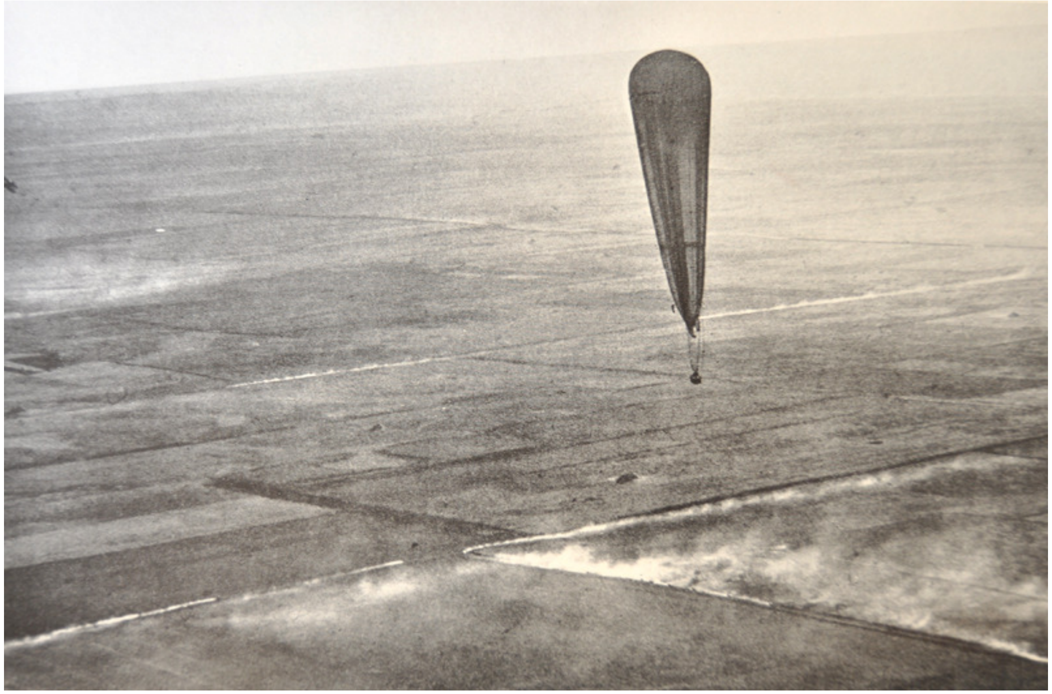
Remote Sensing – history

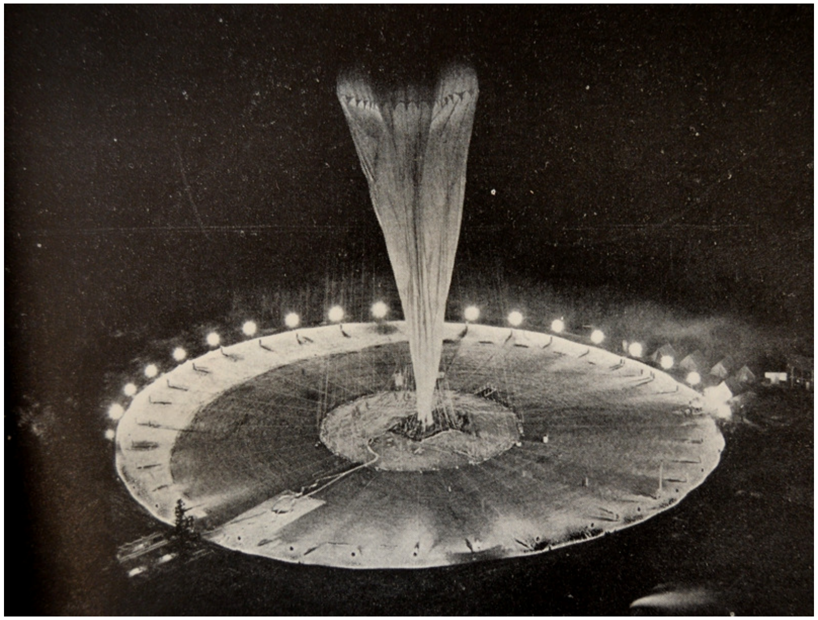
World War I

An aerial photographer and pilot in a Curtiss AH-13 airplane with Graflex camera in 1915

[Jensen 2000]

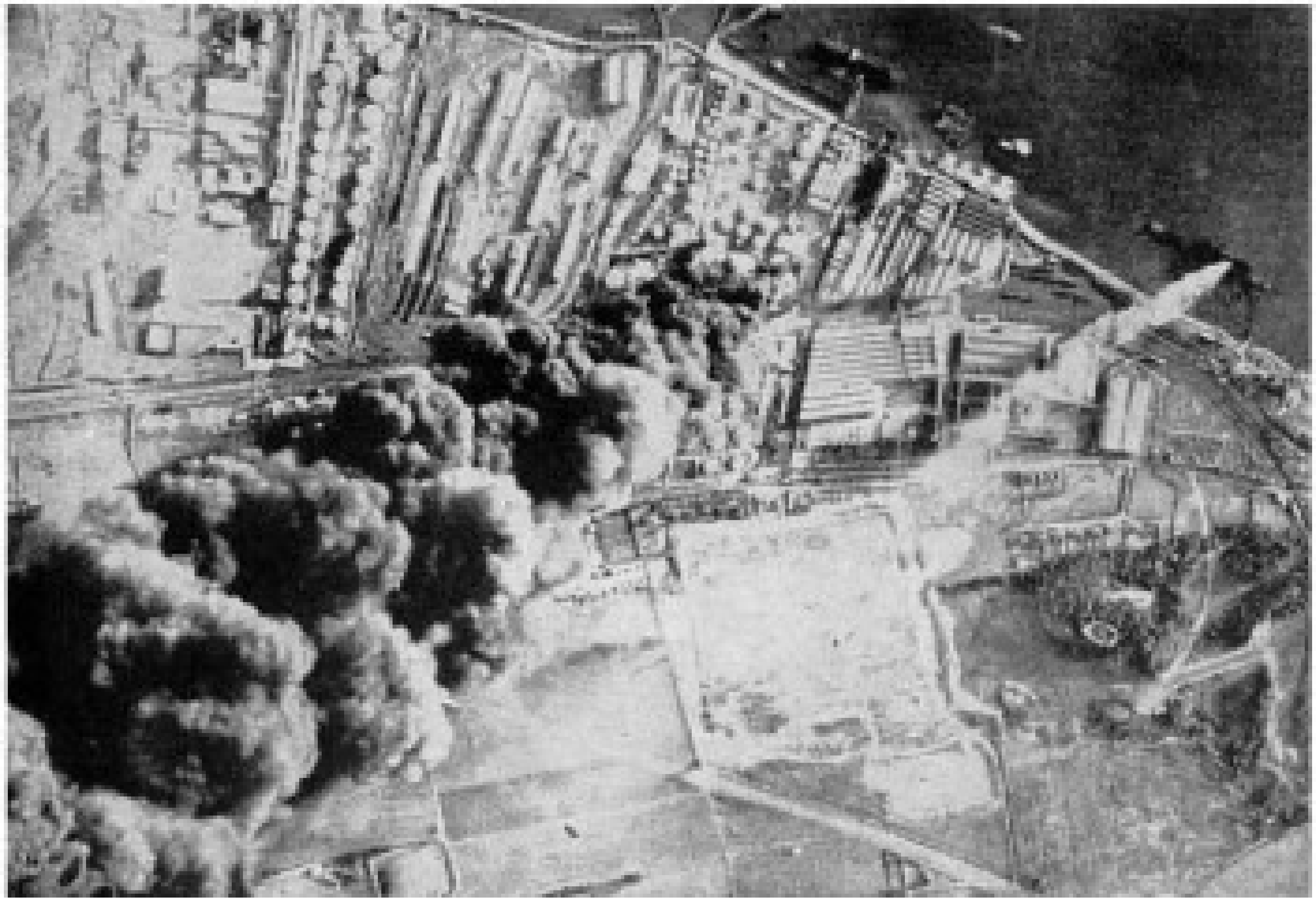
Remote Sensing – history





Before 1946, the highest pictures ever taken of the Earth's surface were from the helium-filled Explorer II balloon, which had ascended 13.7 miles in 1935, high enough to discern the curvature of the Earth.

Remote Sensing – history

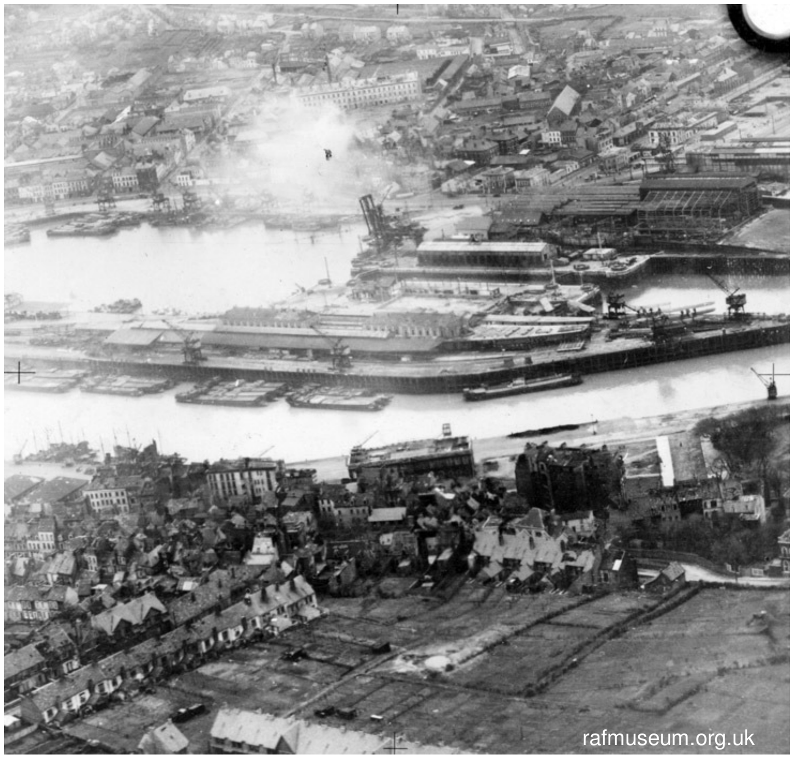


A German photograph of a direct hit on the oil storage tanks at Purfleet, near Tilbury on the Thames

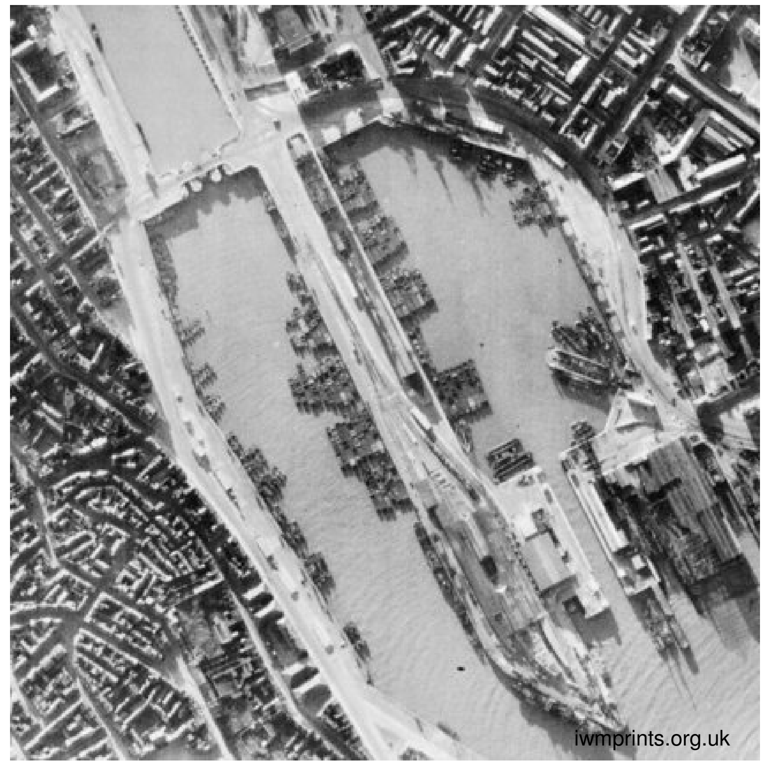
http://nzetc.victoria.ac.nz/tm/scholarly

Remote Sensing – history

World War II



An aerial reconnaissance photograph of German invasion barges



German invasion barges in Boulogne Harbour, France, June 1940.

Remote Sensing – history

World War II

Craters surround a site at Peenemunde in Mecklenburg-Vorpommem, Germany on September 2, 1944, following an Allied bombing raid on the site where the V weapons were designed and tested

A German photograph of a direct hit on the oil storage tanks at Purfleet, near Tilbury on the Thames.

Remote Sensing – history

World War II

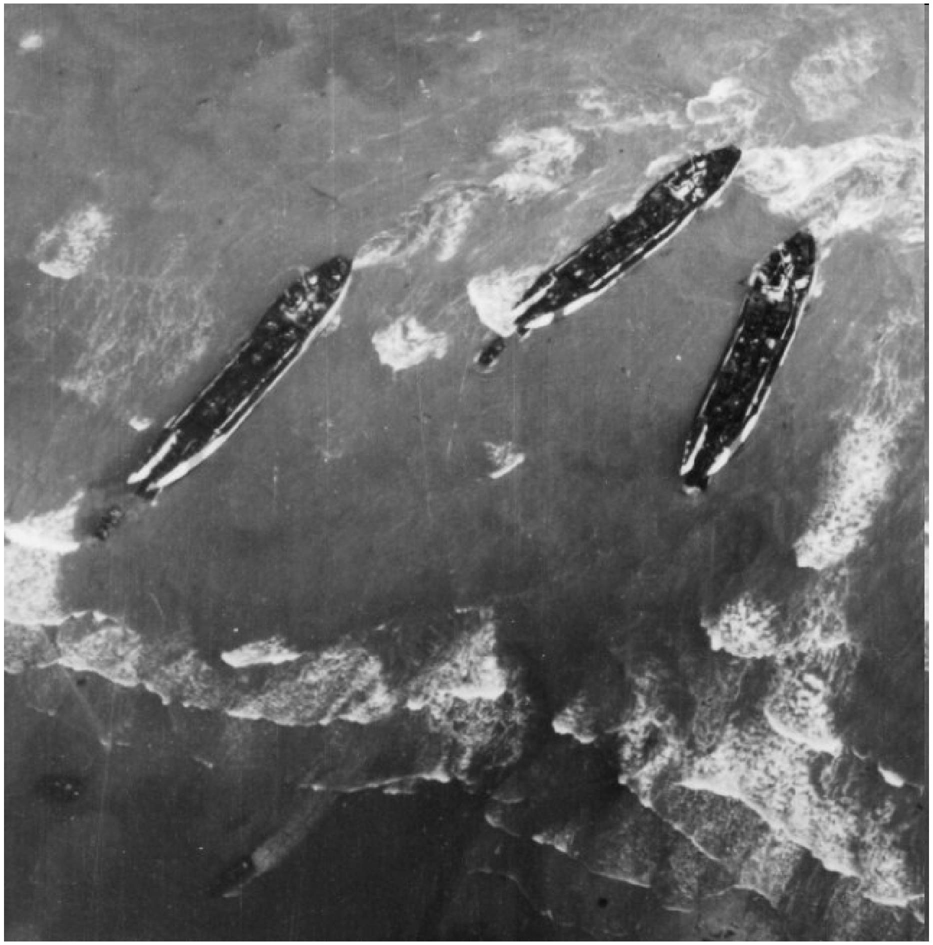
US 8th Air Force B-17 Flying Fortress over Berlin, Germany in World War II.

[Jensen 2000]

Remote Sensing – history

World War II

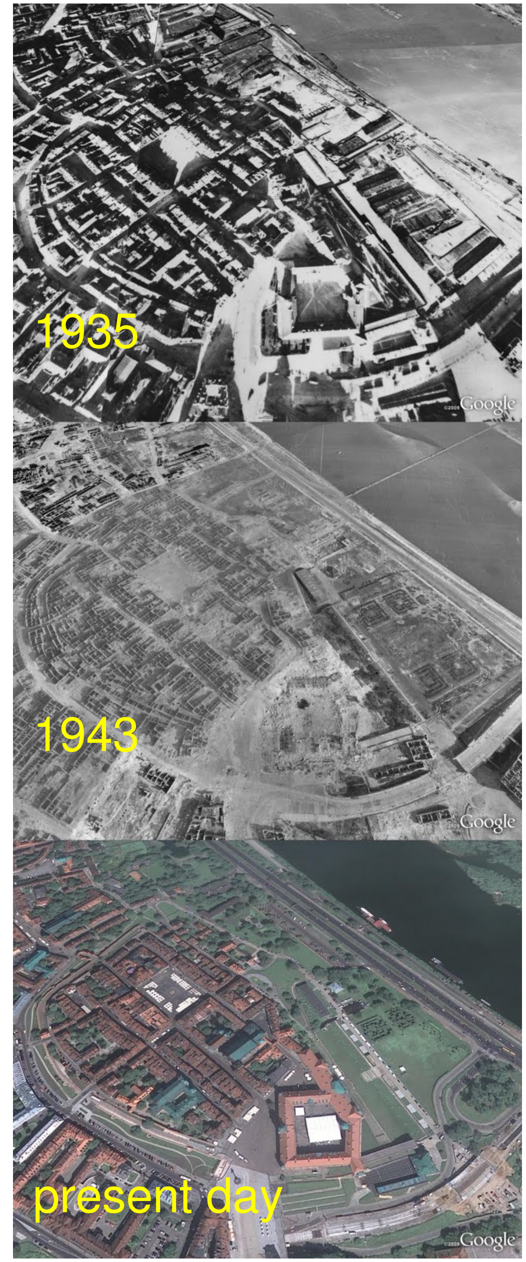
Operation Market Garden in September 1944



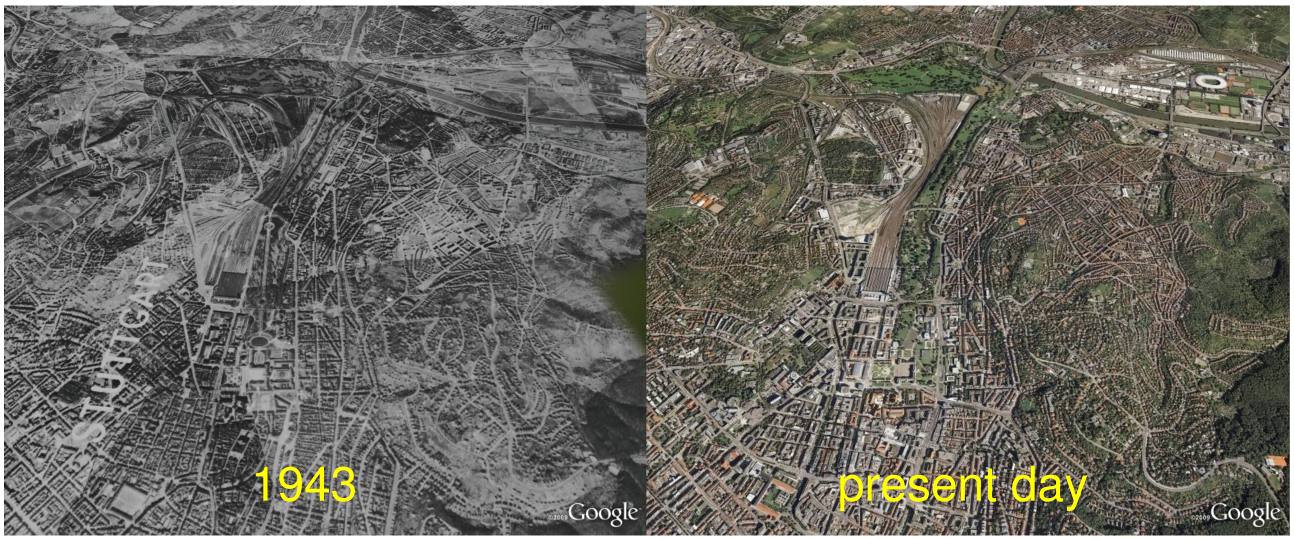
D-Day on June 6, 1944 of the Allied invasion

Remote Sensing – history

Warsaw ghetto



Stuttgart

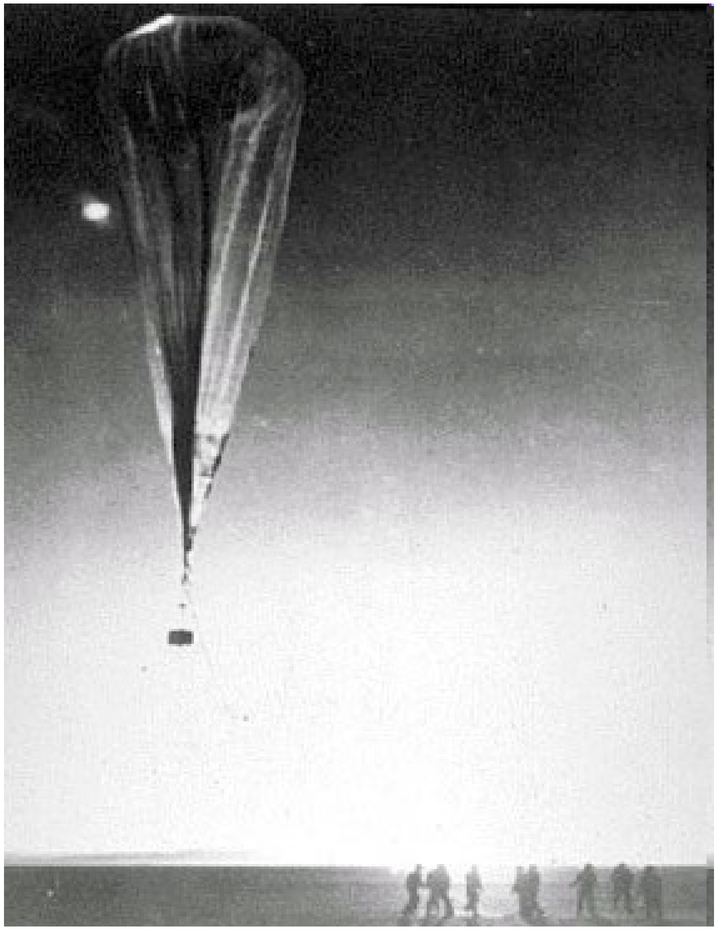


http://gizmodo.com

Remote Sensing – history

Cold War

Grayback Program
Project GENETRIX Balloon



Project GENETRIX Balloon
during launch

This image, taken through a telescope, is of the newly designed super pressure balloon at float altitude over Antarctica.

Credit: Columbia Scientific Balloon Facility

Remote Sensing – history

Cold War

Lockheed U-2 high altitude reconnaissance aircraft
1956

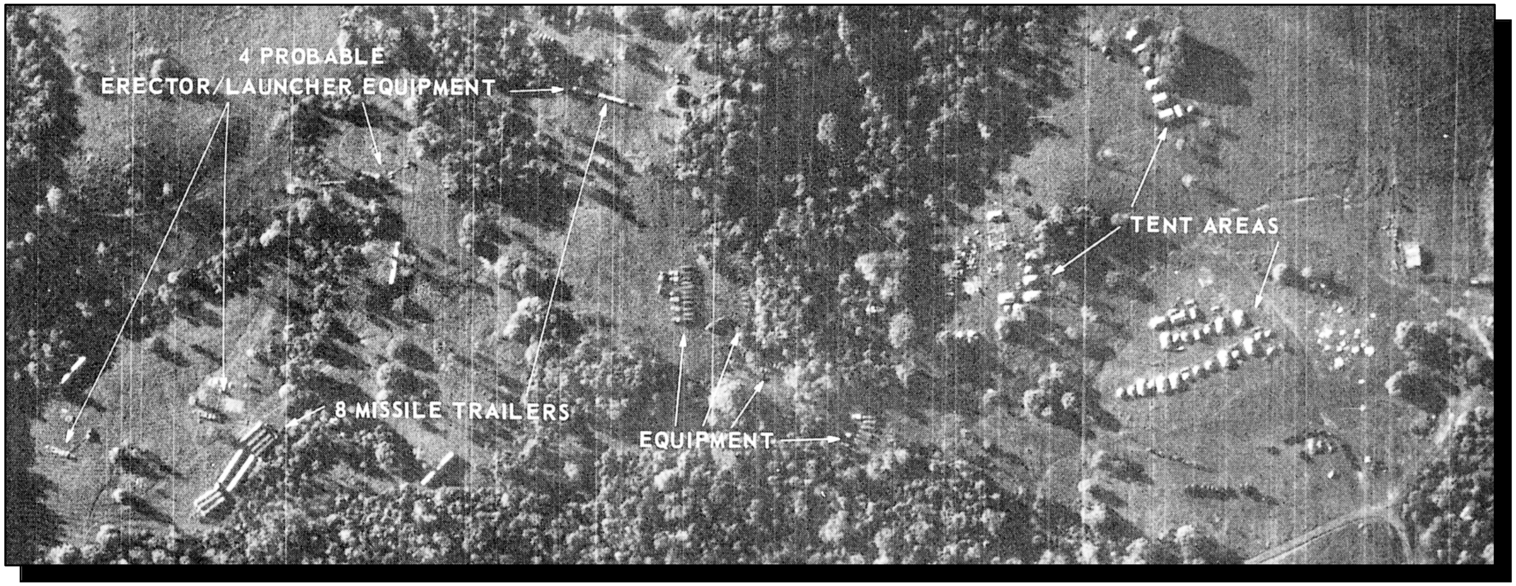
Francis Gary Powers

Two high resolution cameras:

- long-focal-length spotting camera (re-solution 60 cm to 1m from 20 000 m)
- tracking camera to record the flight path

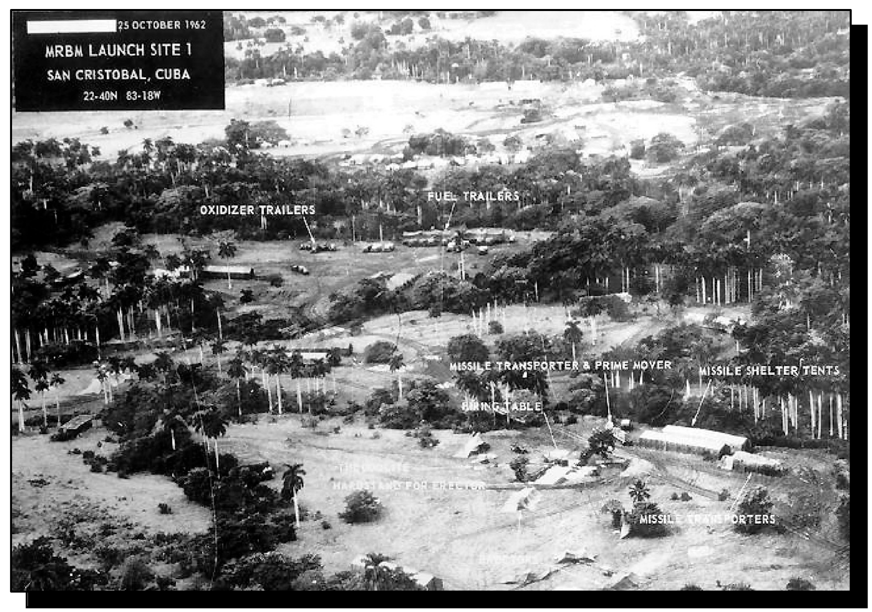
Remote Sensing – history

Cold War



[Jensen 2000]

A portion of the U-2 aerial photograph of San Cristobal, Cuba, 1962 obtained at an altitude of 21 000 m.



Low-oblique aerial photograph of ballistic missile launch site obtained by low-flying RF-101 aircraft.


[redacted] 25 OCTOBER 1962
MRBM LAUNCH SITE 1
SAN CRISTOBAL, CUBA
22-40N 83-18W
OXIDIZER TRAILERS
FUEL TRAILERS
MISSILE TRANSPORTER & PRIME MOVER
MISSILE SHELTER TENTS
FIRING TABLE
MISSILE TRANSPORTERS

[Jensen 2000]

Remote Sensing – history

Lockheed SR-71 reconnaissance aircraft

Remote Sensing – history

First Image From Space - 1946

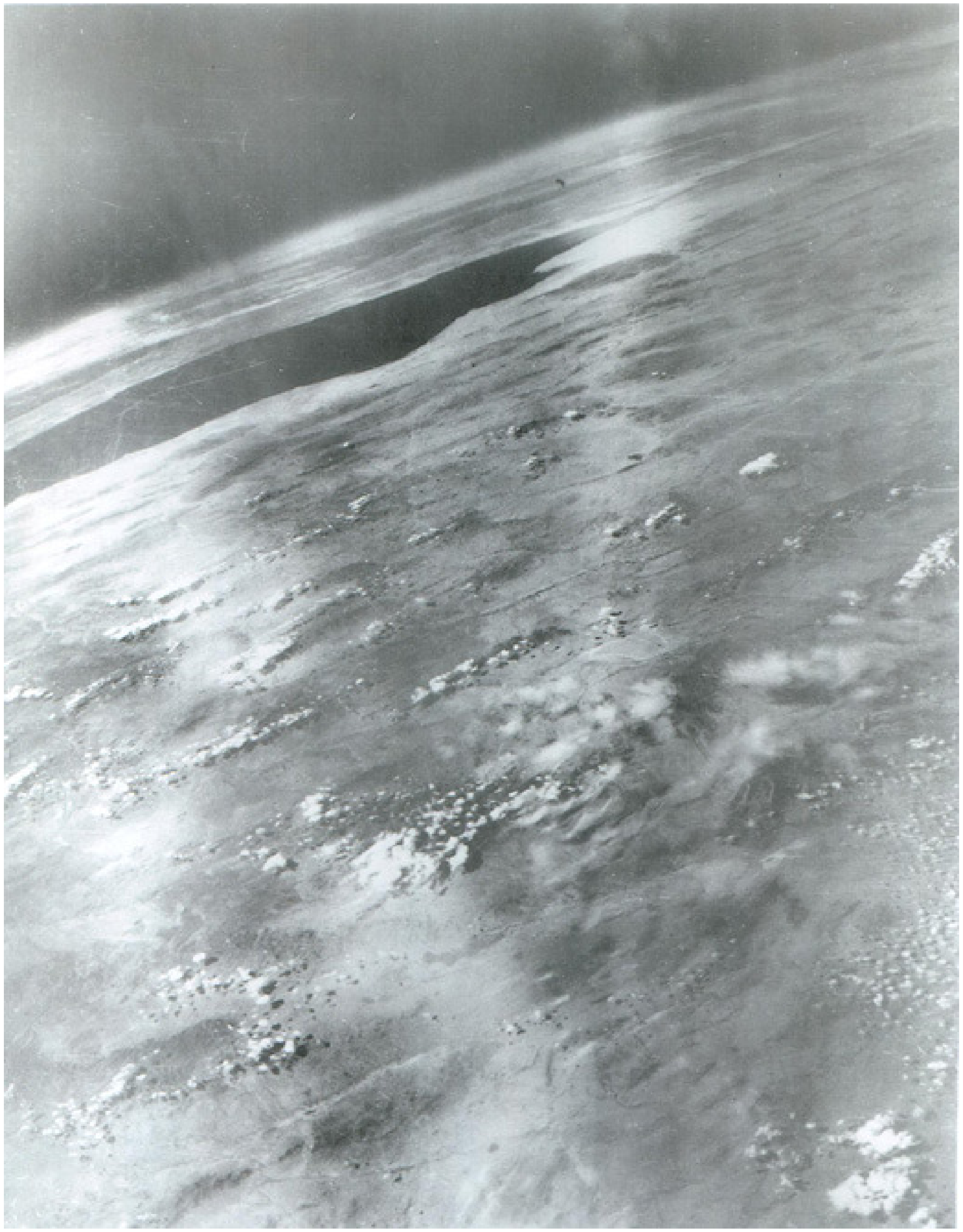
First Image Of The Entire Earth - 1968

Remote Sensing – history

24 October 1946

White Sands (New Mexico)

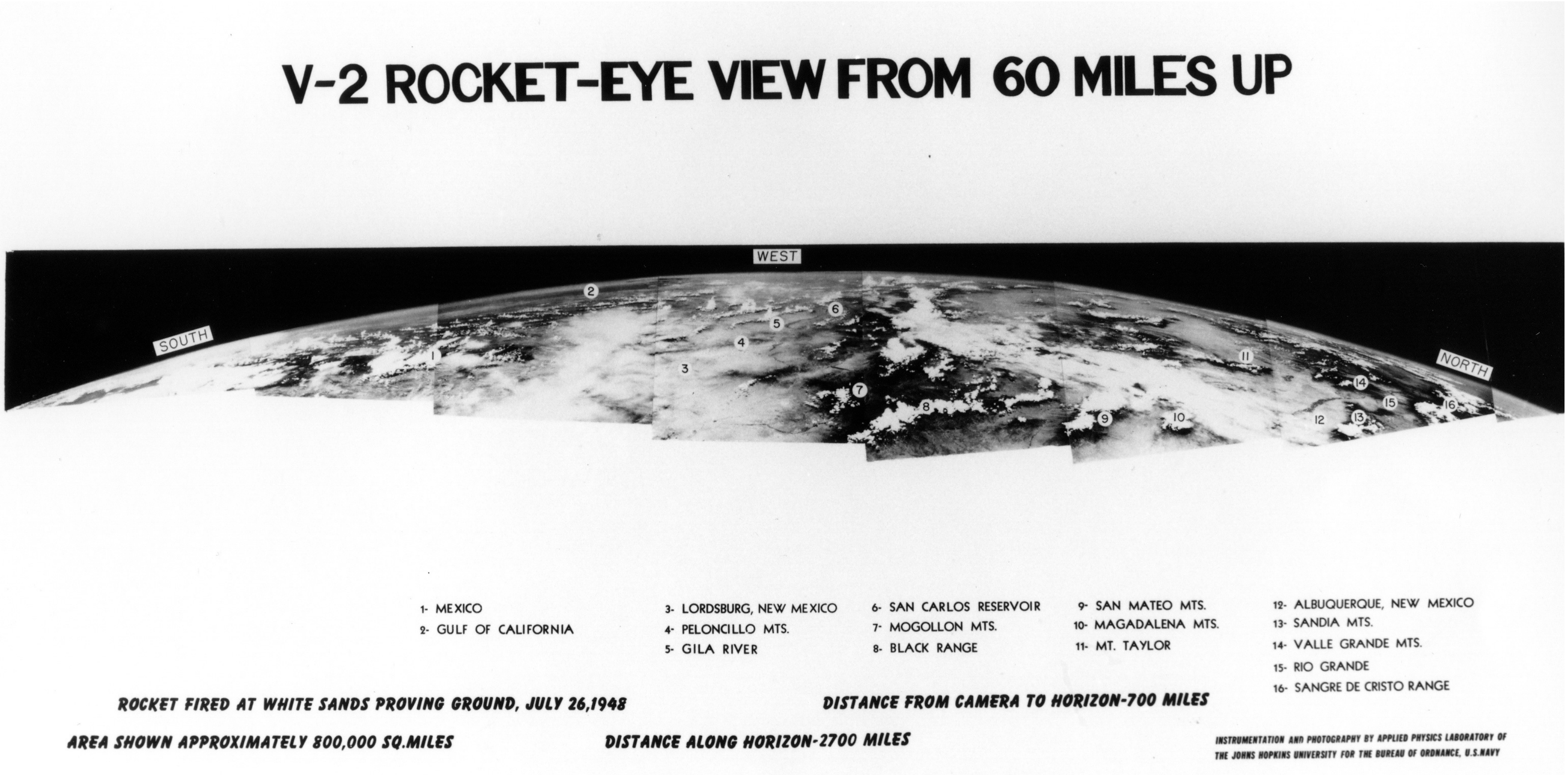
Rocket V2



7 March 1947

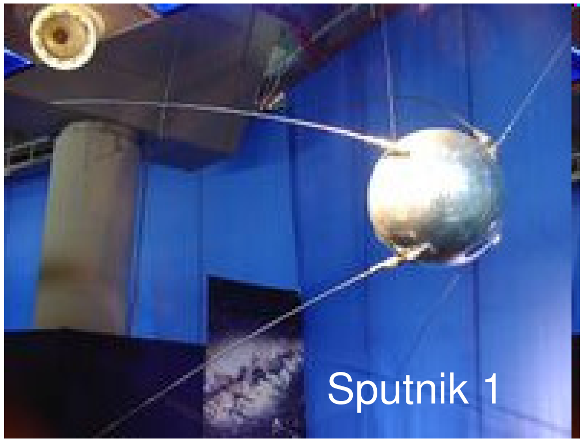
Gulf of California

Remote Sensing – history



A panorama from a July 1948 V-2 shot here.)

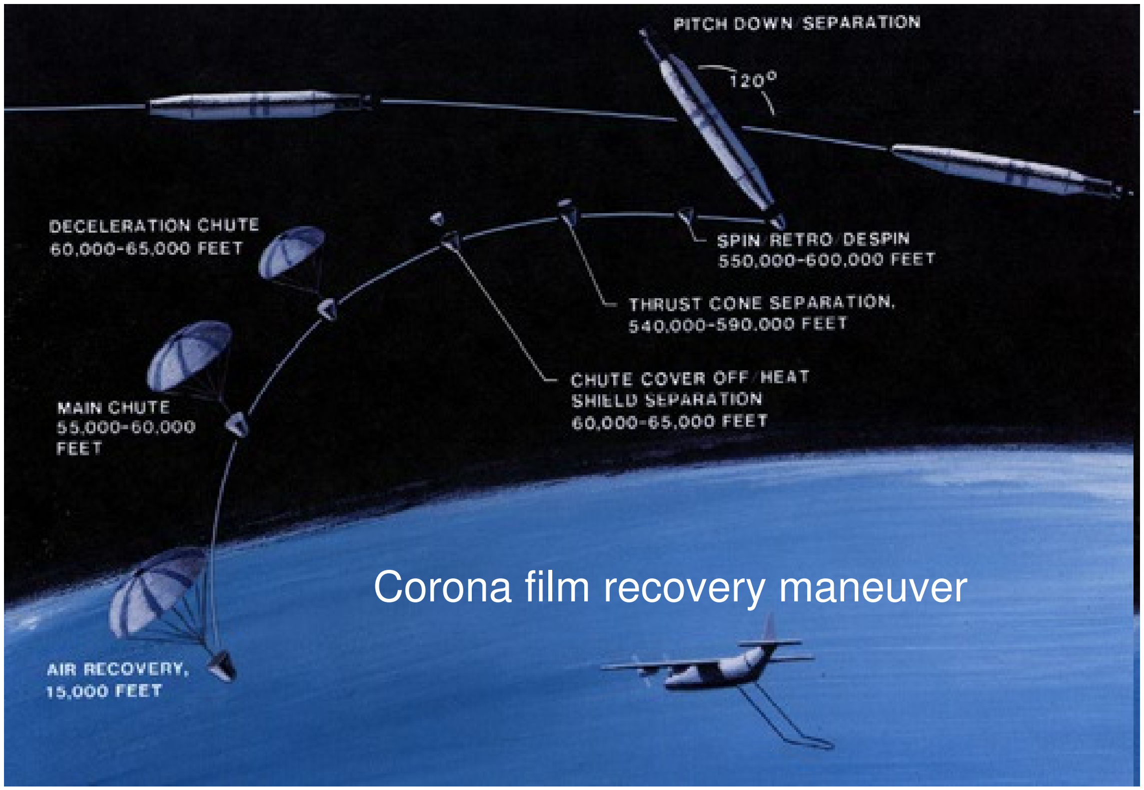
Remote Sensing – history


Sputnik 1

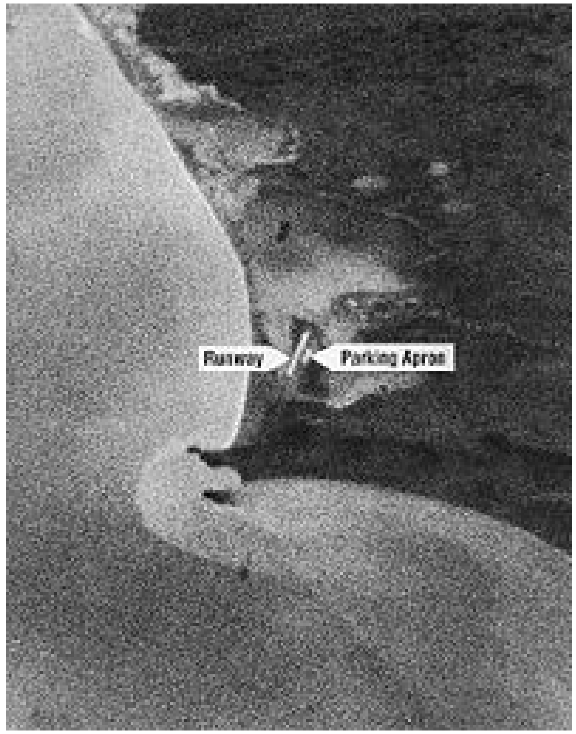
Corona sensors: KH-1, KH-2 … KH-6

Spatial resolution:

KH-1: 12 m (1960)
KH-4B: 1.4 – 1.8 m (1972)



Corona film recovery maneuver



Mys Shmidta Air Field, Chukotka U.S.S.R.
August 18, 1960.
First recovered reconnaissance image
from the Corona spy satellite

The first picture of the whole Earth - 1968

Remote Sensing – history

Satellite image which, according to Americans, confirms that North Korea is preparing to launch a ballistic missile
30.03.2012