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SCHOOL OF CIVIL AND ENVIROMENTAL ENGINEERING

Surveying II
CENG 2092

Chapter 5
Introduction to Remote Sensing, GPS and GIS

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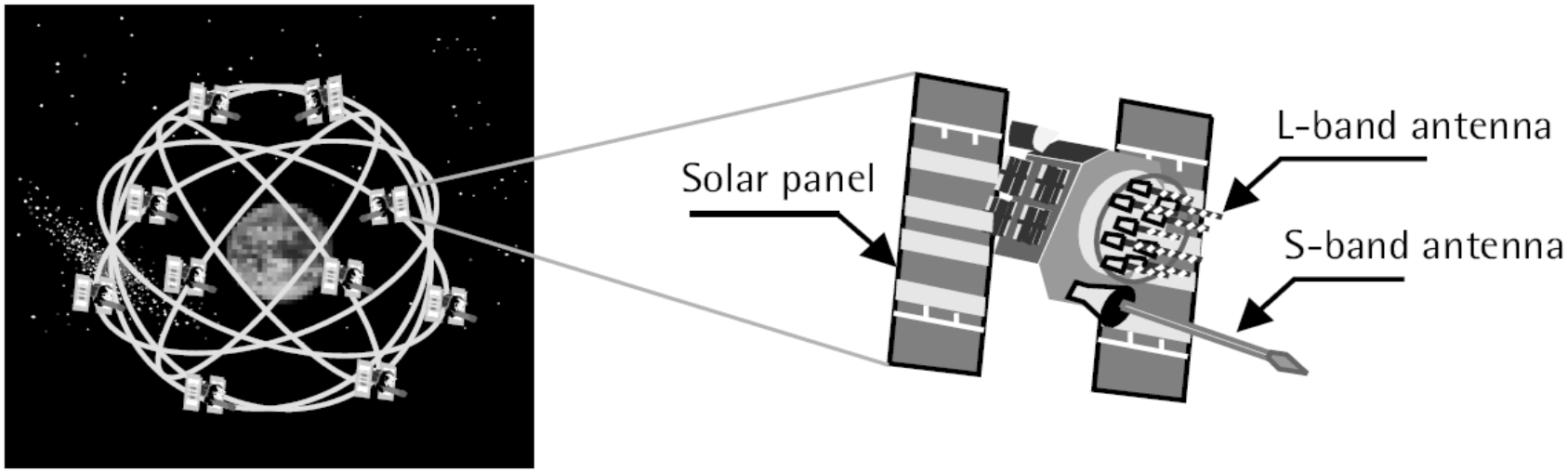
2012EC (2019/20GC)
2nd Sem

GPS overview

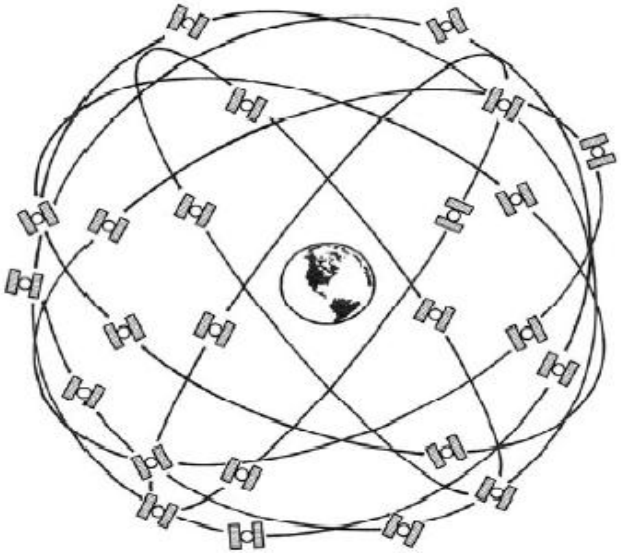
- GPS - Global Positioning System (GPS)
- A satellite-based navigation system
- Developed by the U.S. Department of Defense (DoD) in the early 1970s.
- Provides continuous positioning and timing information
- Serves to an unlimited number of users

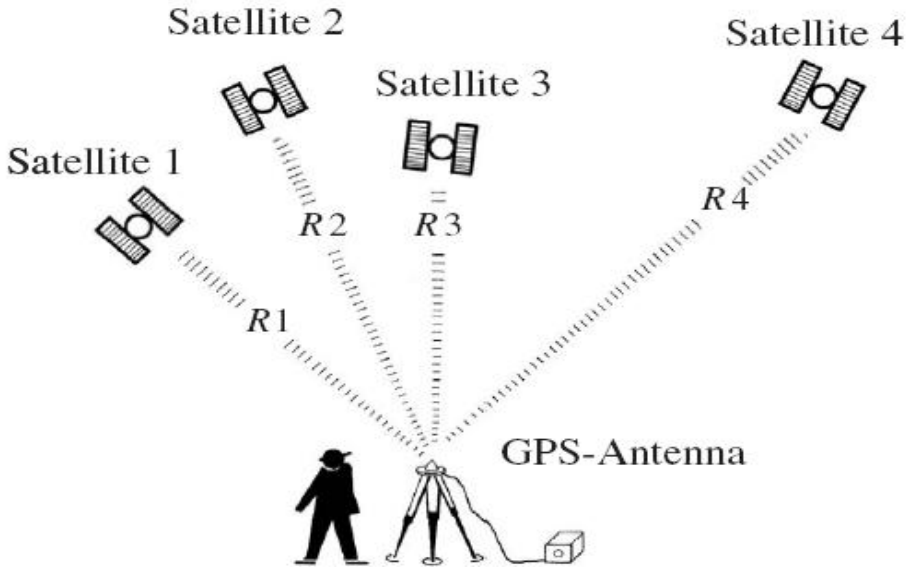
GPS overview cont'd

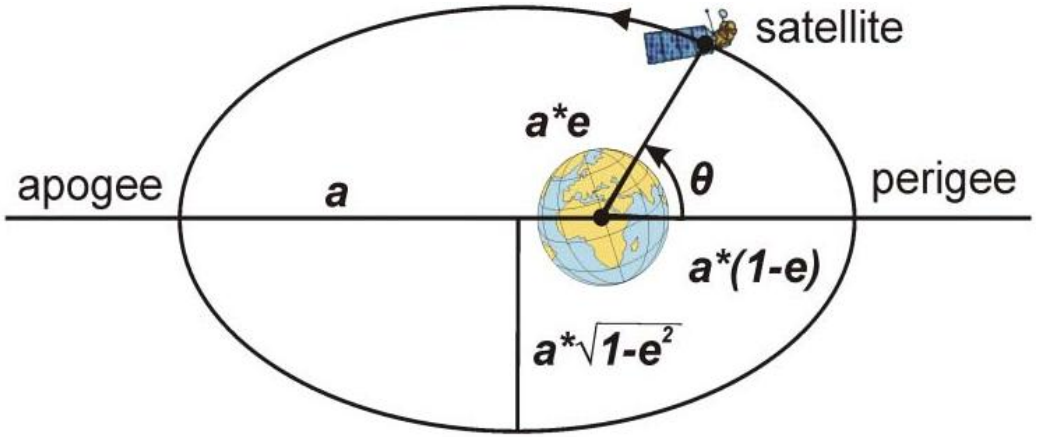
- GPS consists, nominally, of a constellation of 24 operational satellites



Orbits of GPS satellite



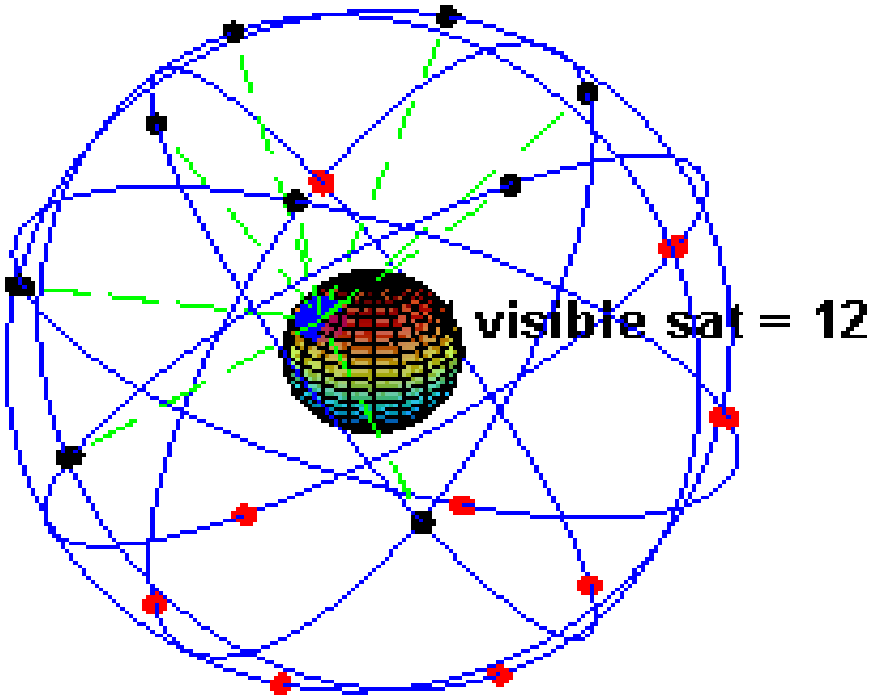




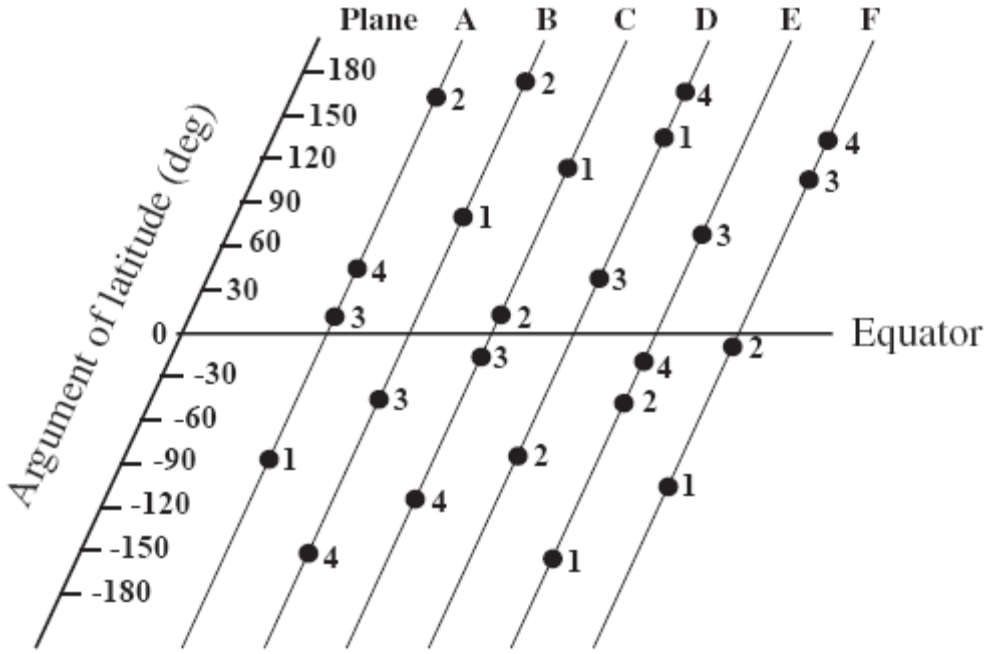
Characteristics of GPS satellite orbit

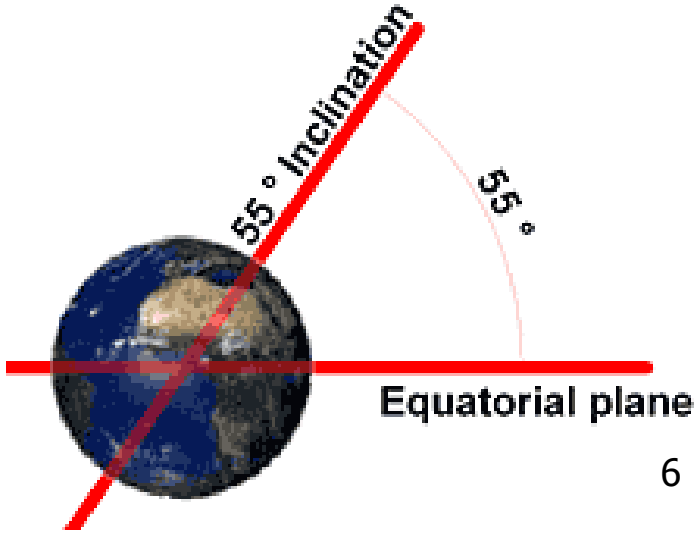
- Satellite revolves at a speed of 3.9 km/s, 11 h 58 min.
- The height is 26560 km from the center of the earth. The height of the orbits above the earth is then about 20200 km.
- Satellites are arranged on 6 planes, each at least 4 slots where satellites can be arranged equidistantly.
- Today, typically more than 24 satellites orbit the earth, improving the availability of the system.
- The inclination angle of 55° , the planes are rotated in the equatorial plane by 60° against each other.

GPS 24 satellites constellation



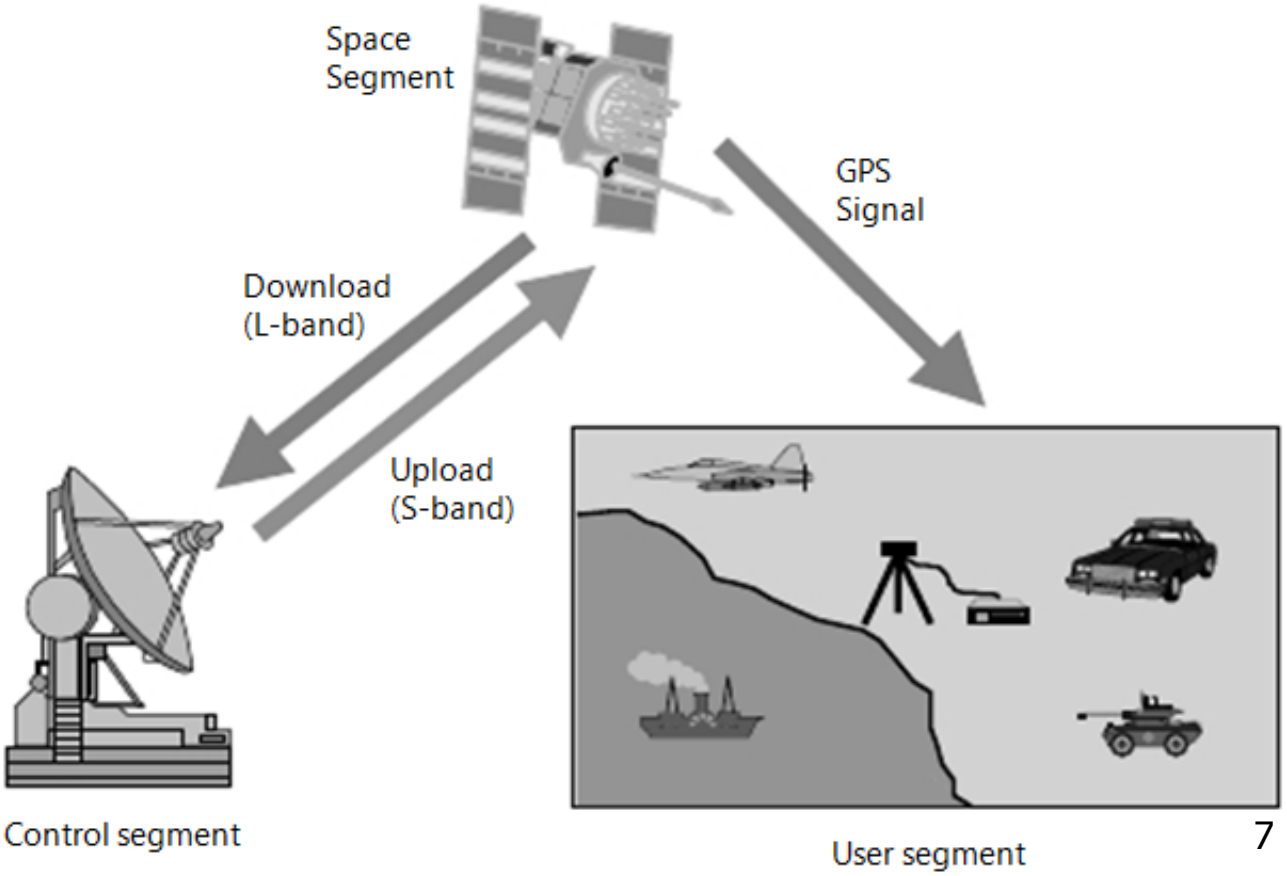
The number and constellation of satellites guarantees that the signals of at least four satellites can be received at any time all over the world.



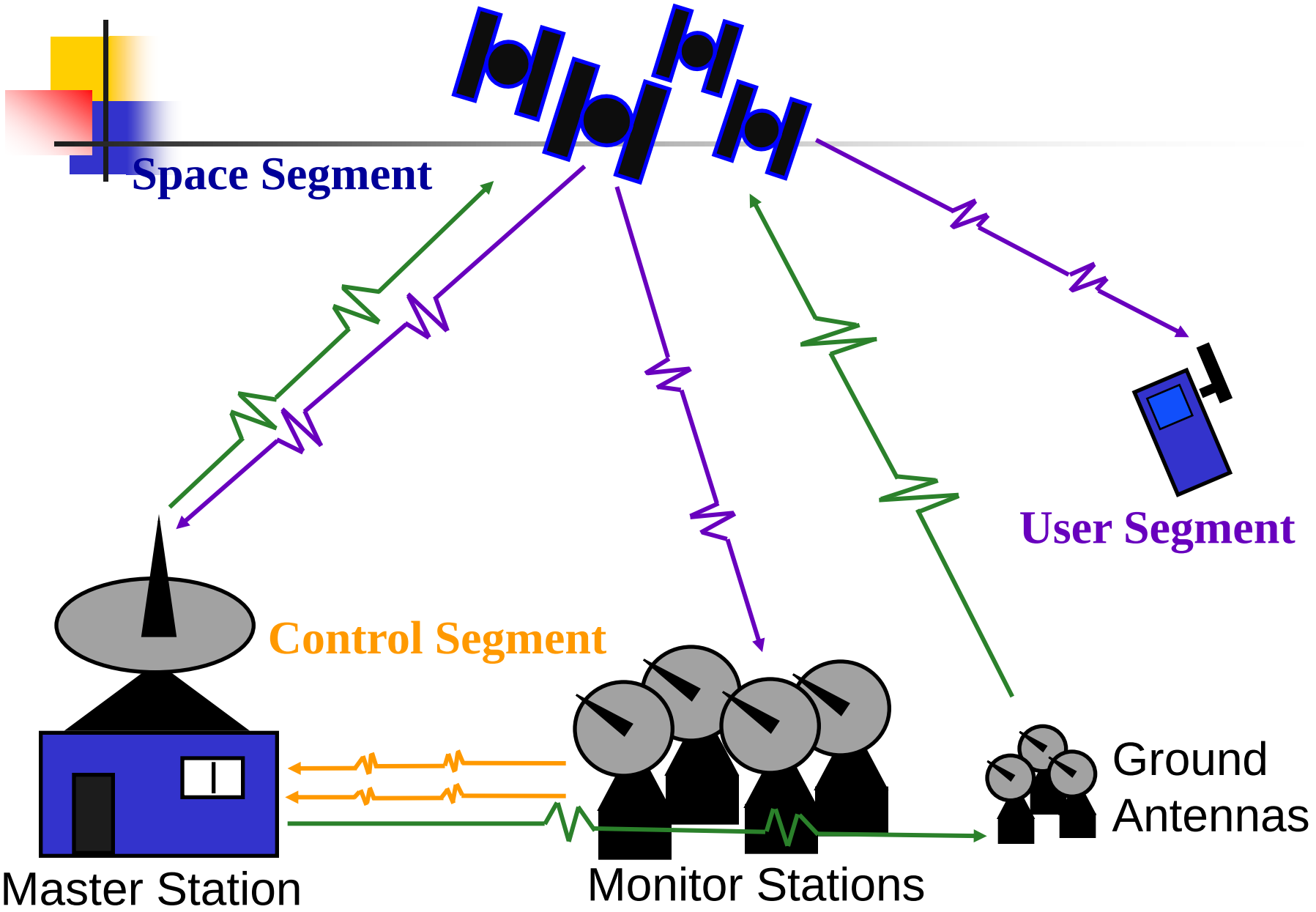


GPS Segments

- Space segment
- Control segment
- User segment

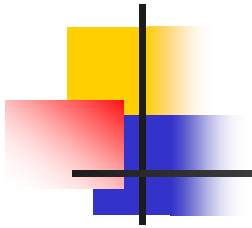


Three Segments of the GPS



Space Segment

- The space segment consists of the 24-satellite constellation
- Each GPS satellite transmits a signal, which has a number of components:
  - two sine waves (also known as carrier frequencies),
  - two digital codes, and
  - a navigation message.
- The carriers and the codes are used mainly to determine the distance from the user's receiver to the GPS satellites.



- The navigation message contains
  - The coordinates (the location) of the satellites as a function of time.
  - Satellite health
- The transmitted signals are controlled by highly accurate atomic clocks onboard the satellites.

Control Segments

- Consists of a worldwide network of tracking stations, with a master control station (MCS) located in the United States at Colorado Springs, Colorado.
- Their primary task is tracking the GPS satellites
  - in order to determine and predict satellite locations
  - system integrity
  - behavior of the satellite atomic clocks
  - atmospheric data
  - the satellite almanac
- This information is then packed and uploaded into the GPS satellites through the S-band link.

Control and Monitor Stations

Tracking station in Hawaii

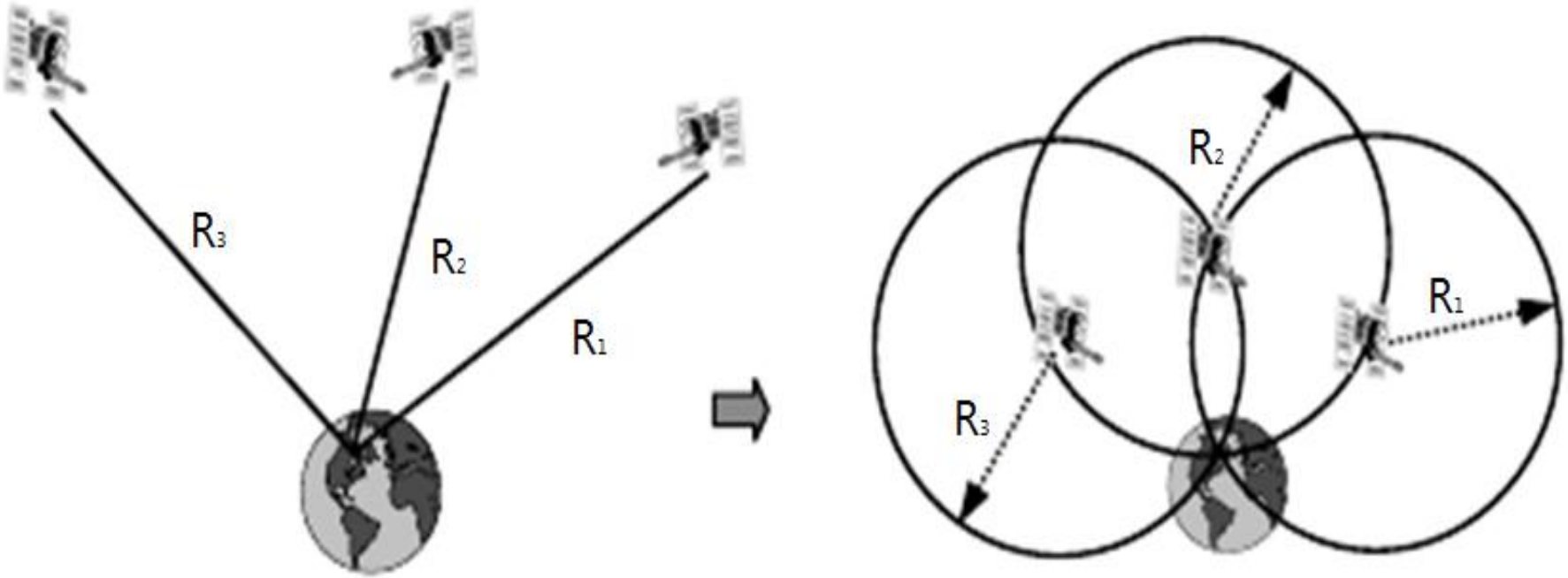
User segment

- The user segment includes all military and civilian users.
- With a GPS receiver connected to a GPS antenna, a user can receive the GPS signals, which can be used to determine his or her position anywhere in the world.
- GPS is currently available to all users worldwide at no direct charge.

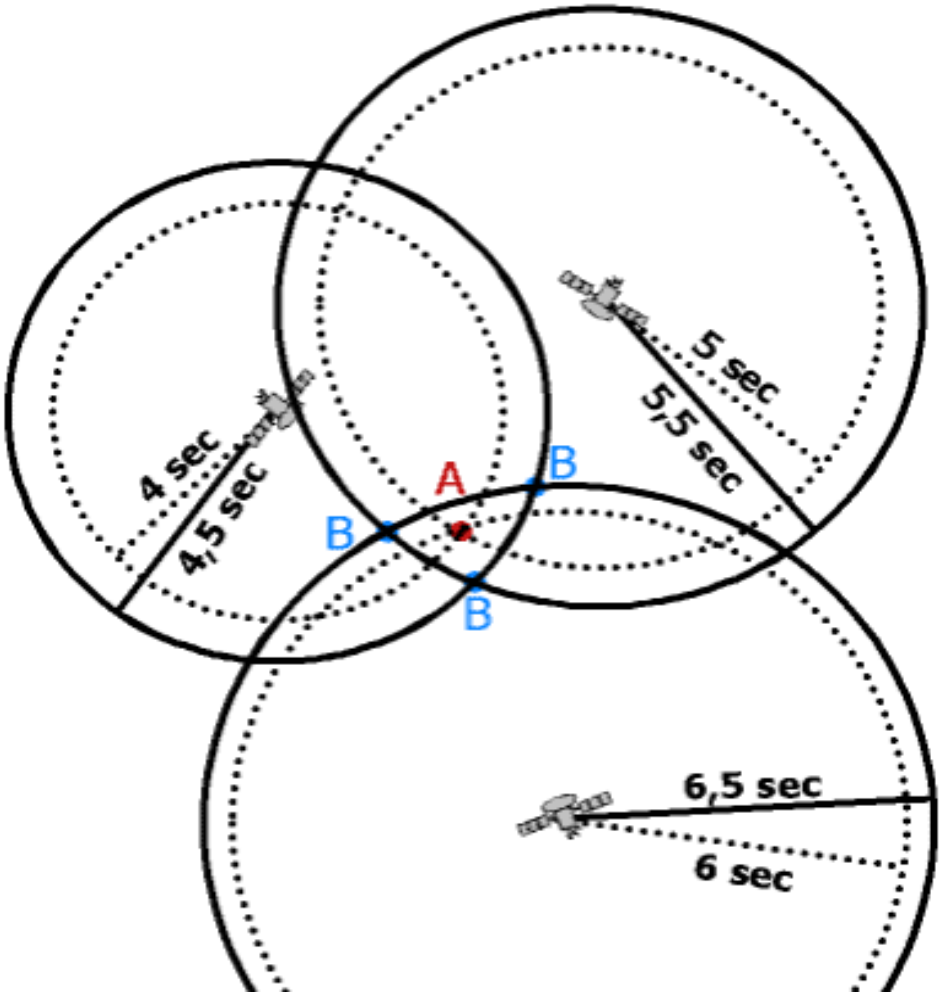
GPS: the basic idea for position determination

- Coordinates of 3 satellite and distances to the receivers are known then the location of the receiver can be calculated by the concept of resection .
- But how we get distances from satellite to receiver and satellite location?
- Distance from two carriers, two codes
- Location of satellite from navigation message.
- Theoretically, only three distances to three satellites are needed.
- By resection method we can calculate the user position.
- From the practical point of view, however, a fourth satellite is needed to account for the receiver clock offset.

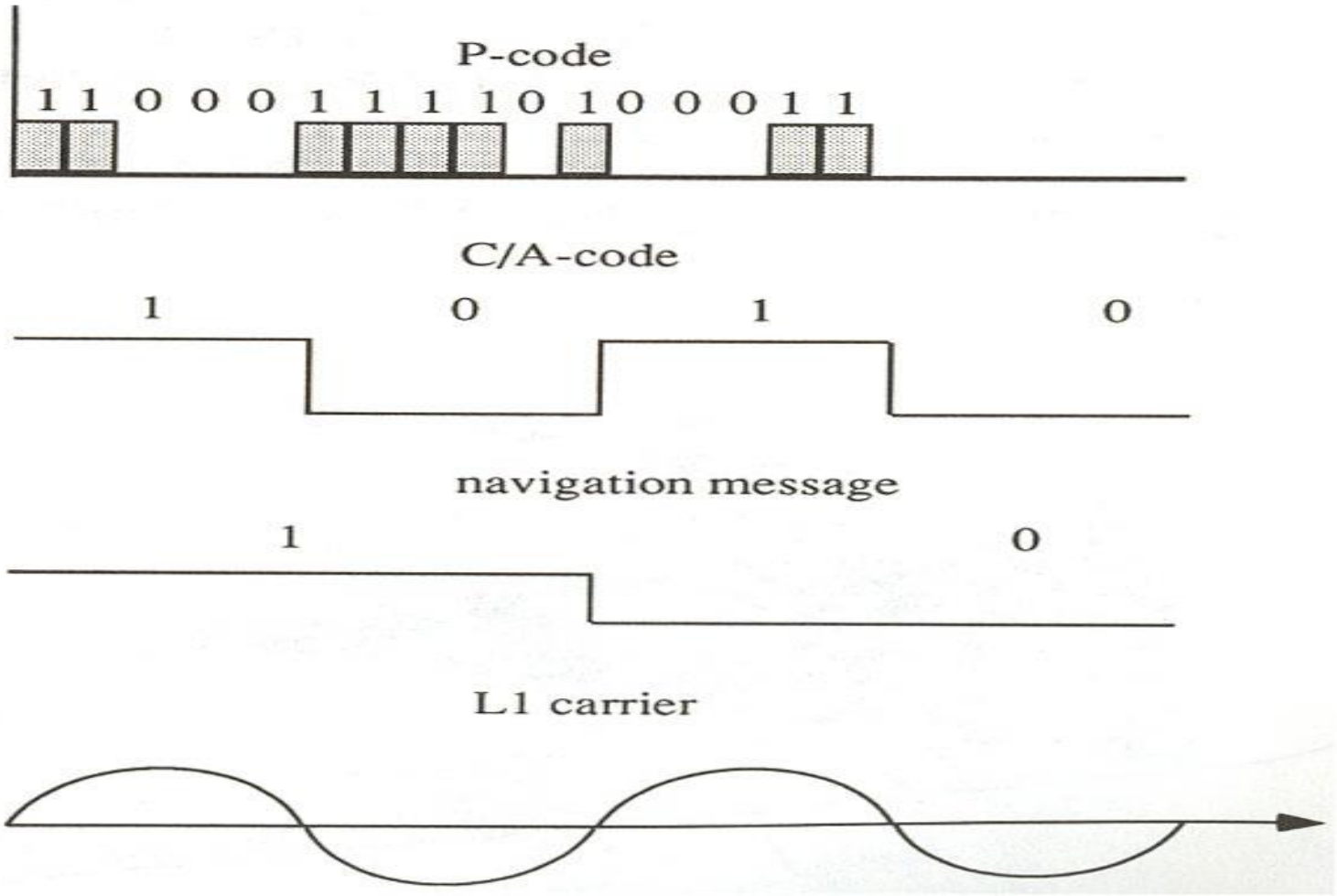
Resection



2D position determination with 3 satellites and corrected clock error



GPS signal structure



C/A, P code, Navigation message

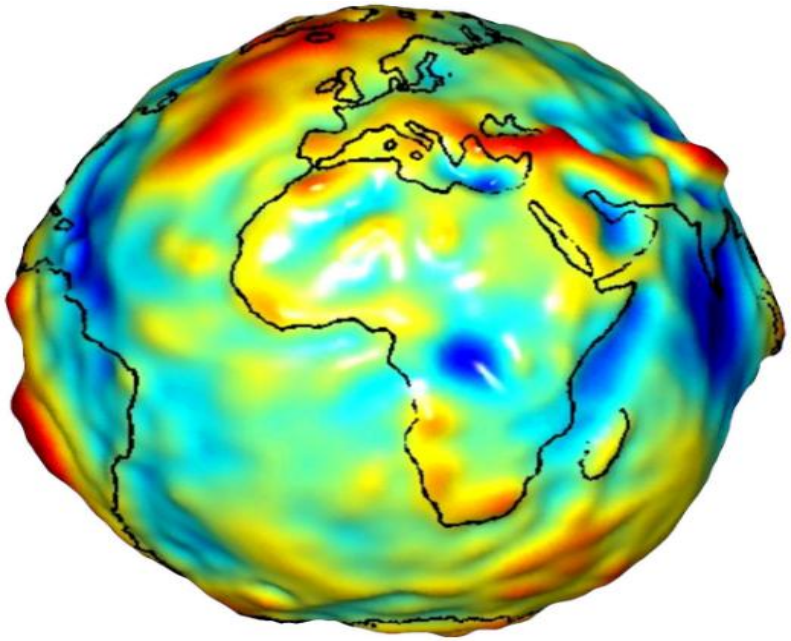
	C/A code	P- code	Navigation Message
Chipping rate	1.023MHz	10.23MHz	50 bit per second
Length per chip	293 m	29.3m	5950 Km
Repetition	1ms	1 week	N/A
Code type	Gold	PRN	N/A
Carriers on	L1	L1,L2	L1,L2
Code nature	Courser code appropriate for initially locking onto the signal.	10 times finer that C/A code	Very course
Included information	Time according to the satellite clock when the signal was transmitted.	Time according to the satellite clock when the signal was transmitted.	Ephemeris, Satellite clock corrections, Almanac data, ionospheric information, and satellite health data.
Application	Moderate Accuracy	High Accuracy	For all the cases

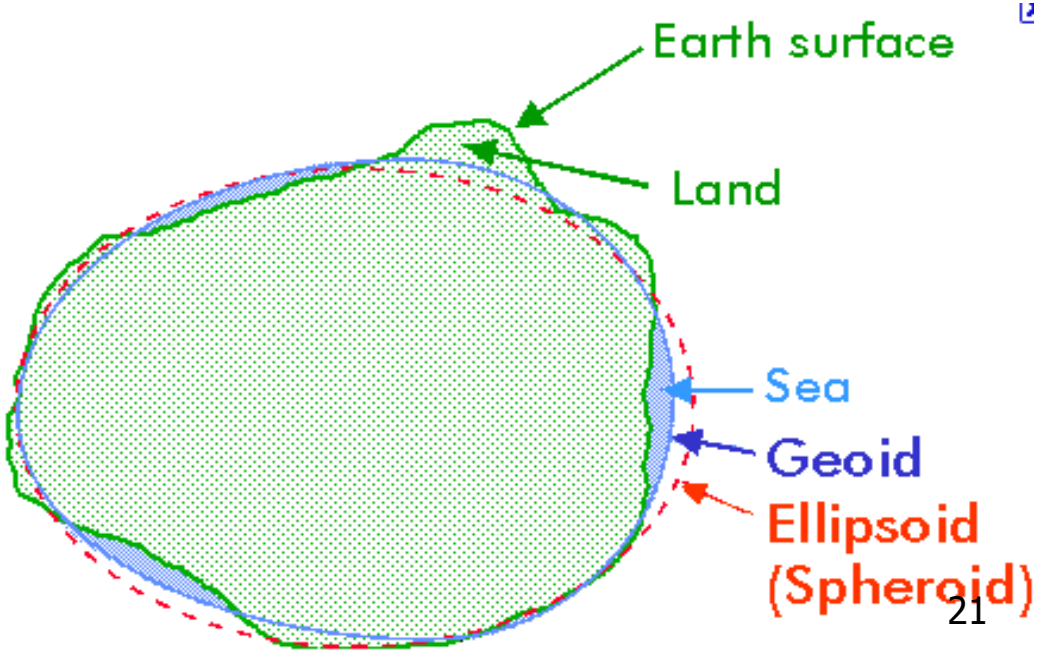
Type of GPS Receivers

- Single-frequency code receivers (L1)
- Single-frequency carrier-smoothed code receivers
- Single-frequency code and carrier receivers

GPS Coordinate System

- The reference ellipsoid used of GPS work is the **WGS84** ellipsoid . With semi major axis (a) = 6378137m and f= 1/298.257223563.
- Can be customized to give in local coordinate system (e.g. for Ethiopia – Adindan)



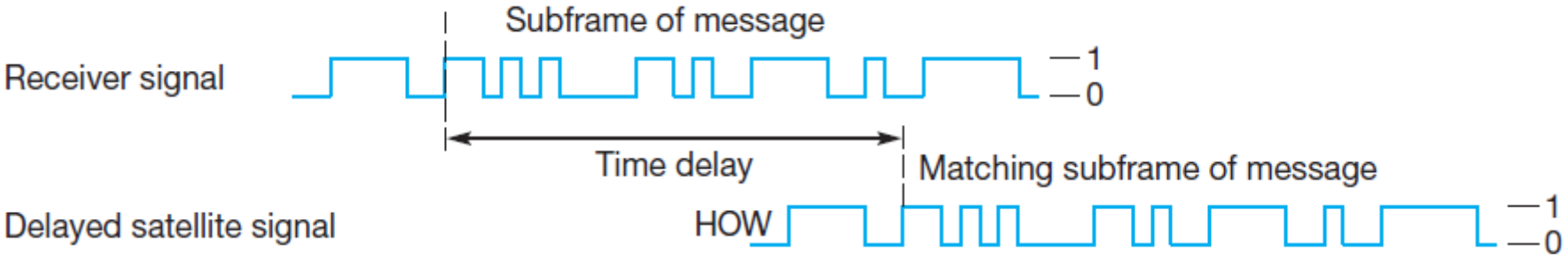


Fundamentals of GPS positioning

- GPS receivers in determining distances to satellites employ two fundamental methods:
  - Code
  - Carrier

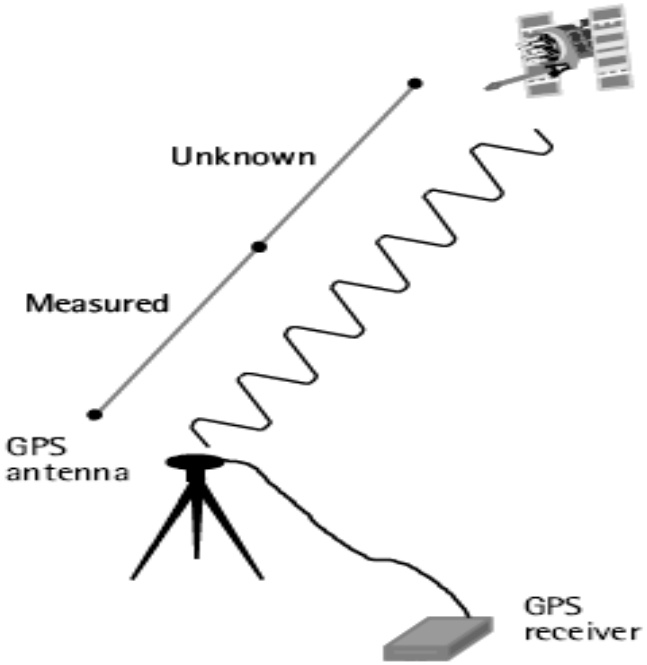
Code Pseudo-range measurement

- Distance = Travel time x Speed of light



Carrier- Phase measurement

- The range would simply be the sum of the total number of full carrier cycles plus fractional cycles at the receiver and the satellite, multiplied by the carrier wavelength.

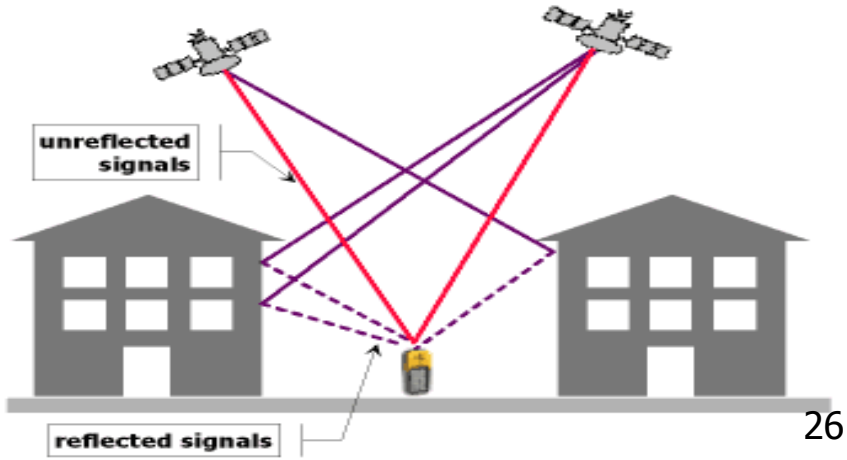


Errors in GPS observation

- Satellite Dependent
  - Satellite clock error: accurate but not perfect
  - Satellite ephemeris errors: d/ce b/n actual and expected position
  - Satellite geometry: relative position of satellite as seen by receiver

Signal propagation dependent

- Ionosphere: delays code & advances carrier
- Troposphere: non dispersive media → delays GPS carriers and codes
- Multi path: one or more reflected signals reach the antenna



Interference caused by reflection of the signals

Receiver Dependent

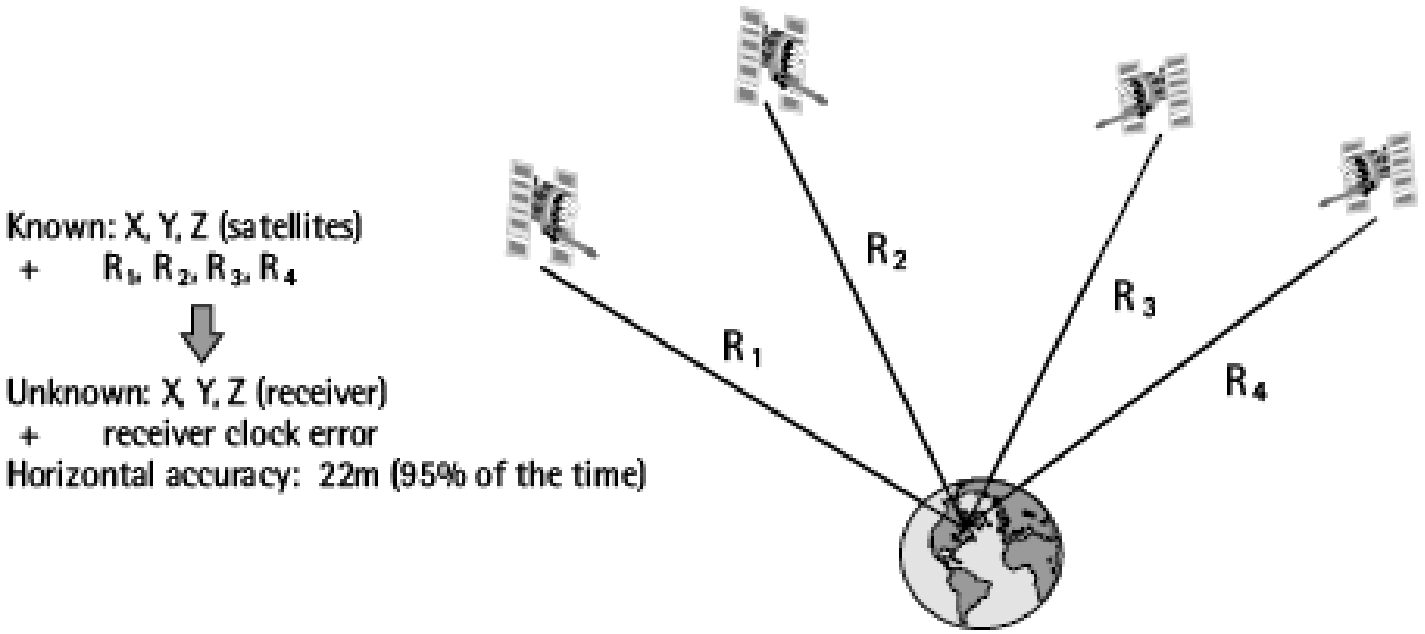
- Receiver clock: less accurate crystal clocks
- Antenna phase-center variation: Antenna-phase-center is the point on the receiver at which the signal is received → This point is different from the geometric center of the antenna

Types of error in GPS system with approximate values

Types of errors	Magnitude of the error
Ionospheric effects	± 5 meters
Shifts in the satellite orbits	± 2.5 meter
Clock errors of the satellites' clocks	± 2 meter
Multipath effect	± 1 meter
Tropospheric effects	± 0.5 meter
Calculation and rounding errors	± 1 meter

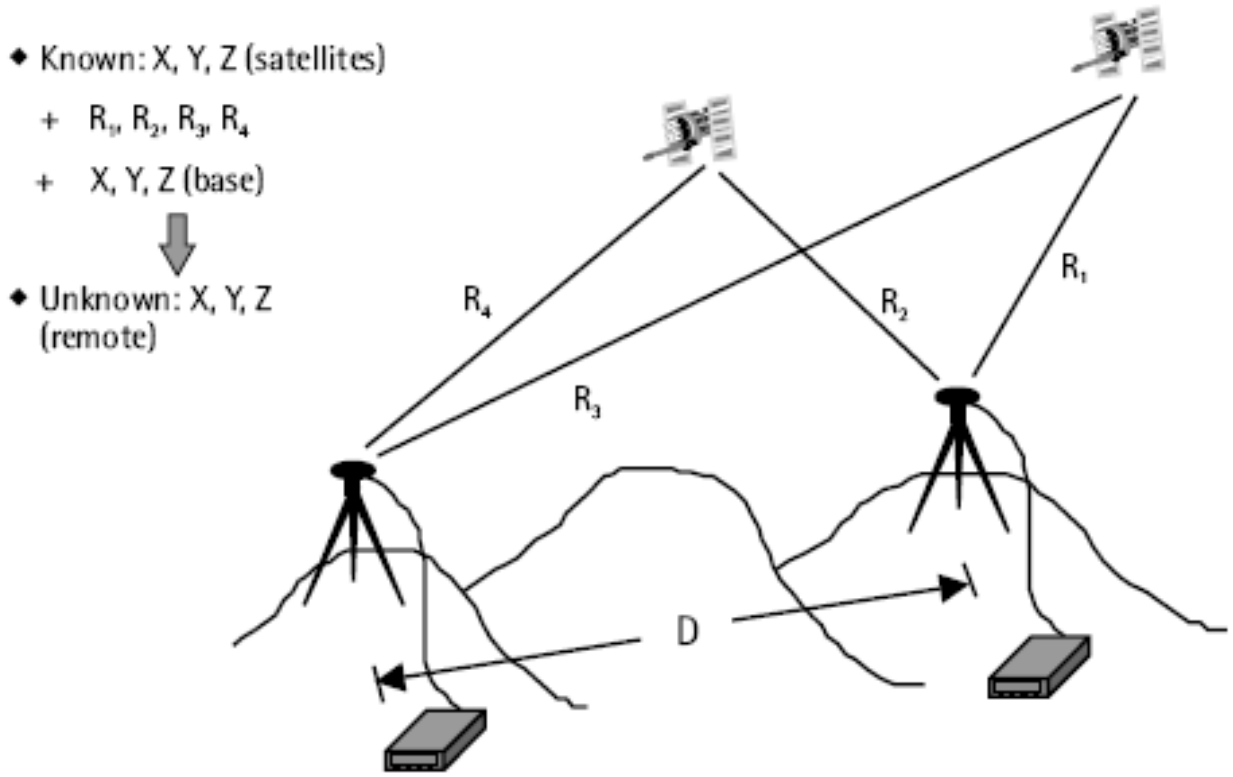
GPS Positioning Mode

Point Positioning: employs one GPS receiver that measures the code pseudo-ranges to determine the user's position



Relative Positioning

employs two GPS receivers simultaneously tracking the same satellites to determine their relative coordinates.



Relative positioning

- **Static GPS surveying:** is a relative positioning technique that depends on the carrier phase measurements. It employs two or more receivers simultaneously tacking the same satellites

- **RTK GPS is** a carrier phase based relative positioning technique that like previous methods employs two (or more) receivers simultaneously tracking the same satellites. The position is determined at real time.

- **Real time differential GPS** is a code based relative positioning technique that employs two or more receivers simultaneously tracking the same satellites.

GPS For Engineering

- Road construction
- Pile foundation positioning
- Precise structure placement (Prefabricated)
- Setting out

A dozer and grader using machine control to create an intersection of roads.

GNSS antenna mounted on a grader blade.

GPS receiver being used in construction stakeout (setting out)

Advantages of GPS over other ground methods

- Inter-visibility between the points is not required with GPS. This means that extensive traversing is eliminated
- GPS provides user-defined coordinates in a digital format, which can be easily exported to any GIS system for further analysis.
- The accuracy obtained with GPS is consistent over the entire network; such accuracy is lacked by conventional surveying methods.
- Also, with GPS, one reference station can support an unlimited number of rover receivers.
- Use of GPS in cadastral surveying is cost-effective.

Other Satellite navigation systems

- Russia has a system called Glonass (24)
- Several countries have already developed regional augmentation to the GPS (and Glonass) signals, using geostationary satellites. (WAAS in the USA, MS AS in Japan and EGNOS in Europe)
- The European Galileo coming in near future. (2)
- Compass China (1)

INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEM

Data VS Information

Data

→Unprocessed raw information

Information

→The result of processing, manipulating and organizing data in a way that adds to the knowledge of the person receiving it

Information System

- Information system is a system used for capturing, storing, organizing, manuplating and analyzing data

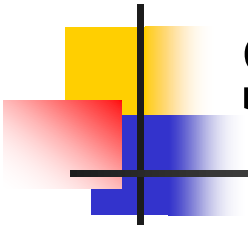
Geographic Information

- Information about places on Earth's surface

  Geographic versus *spatial*

  Geographic refers to Earth's surface and near surface

  Spatial refers to any space (more general)
- Knowledge about *where* something is
- Knowledge about *what* is at a given location



Spatial Data

Can be very detailed or very course

- building in engineering faculity
- commercial buildings in Addis

Can be relatively static or change rapidly

- geological information
- hourly traffic information

Can be very sparse or voluminous

Geographic Information System

- System of hardware, software, data and organizational structure for capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to positions on the Earth's surface

What Makes Up A GIS?

GIS functions

Capture

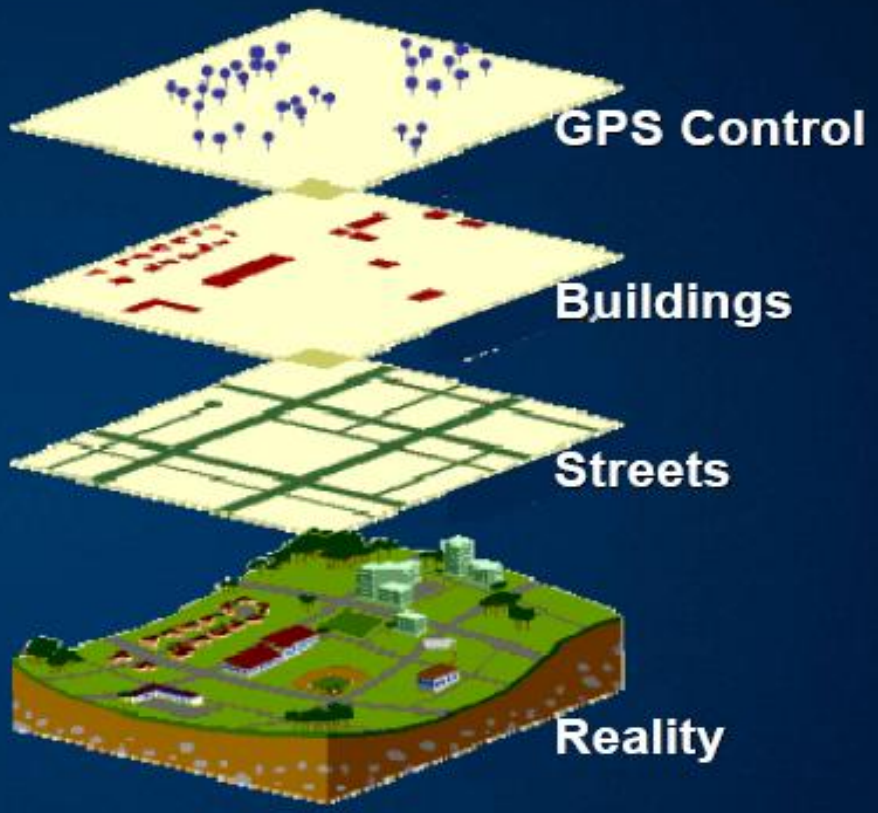
Store

Query

Analyze

Display

Output



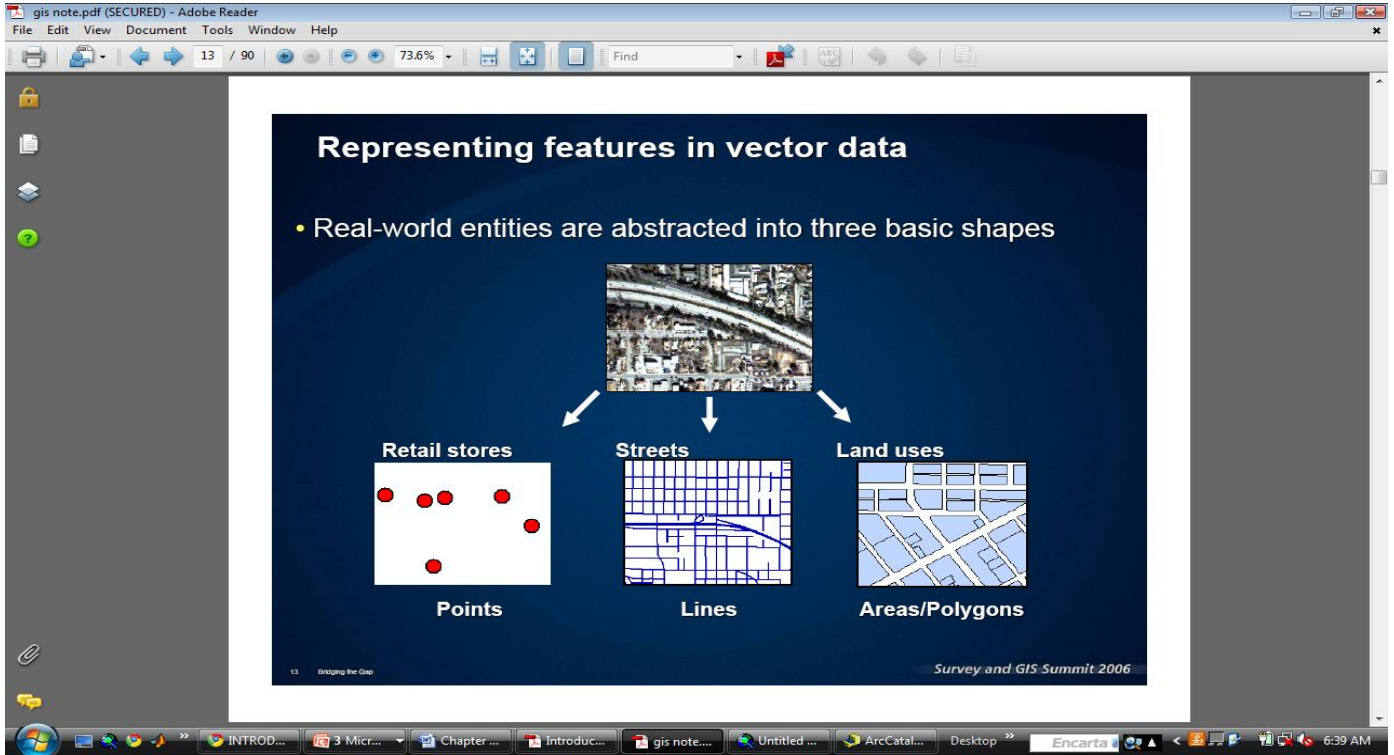
GIS Data Types

- Spatial Data
- Attribute Data
- Meta Data

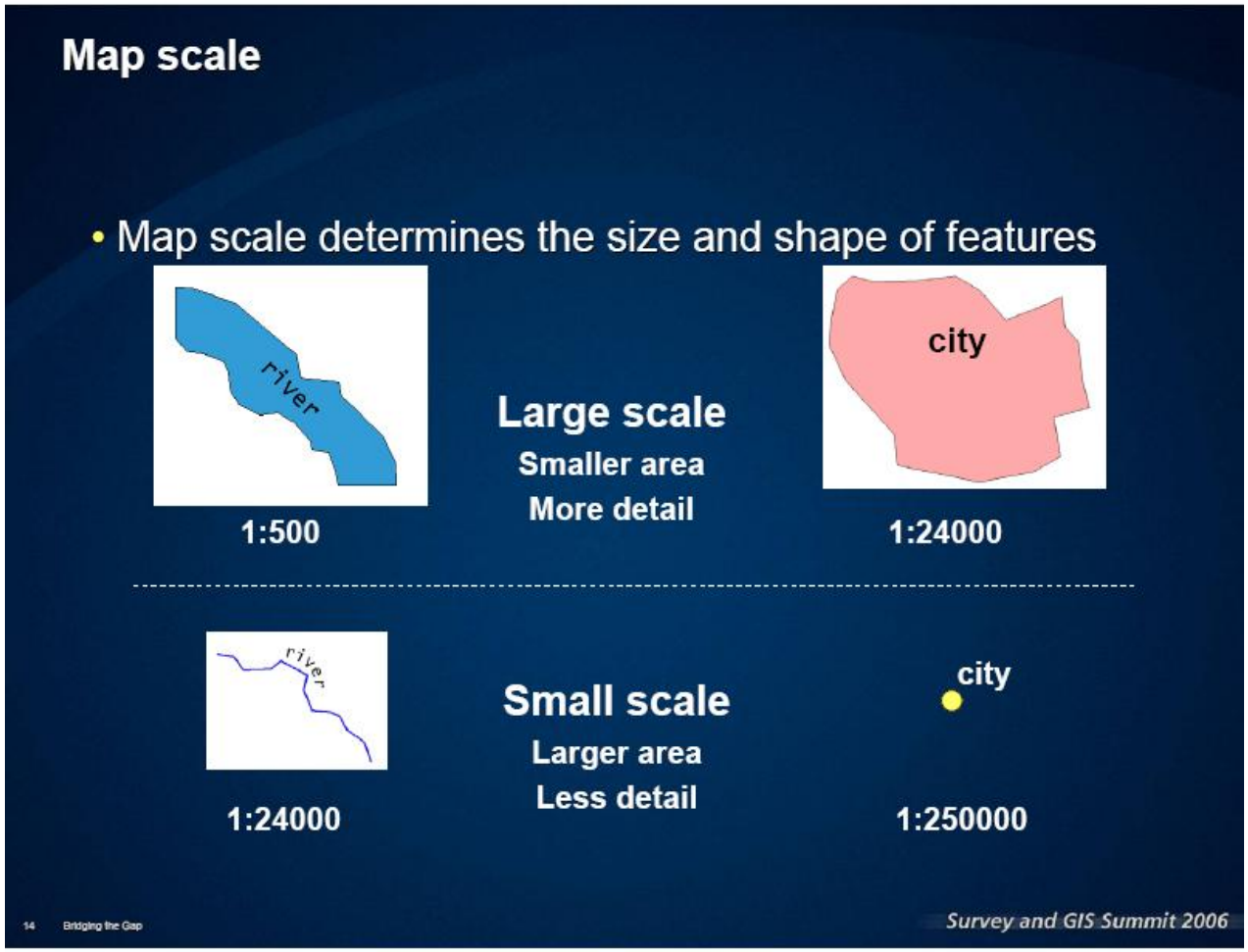
GIS Data Types

1. Spatial Data

- vector data (point, line, polygon)



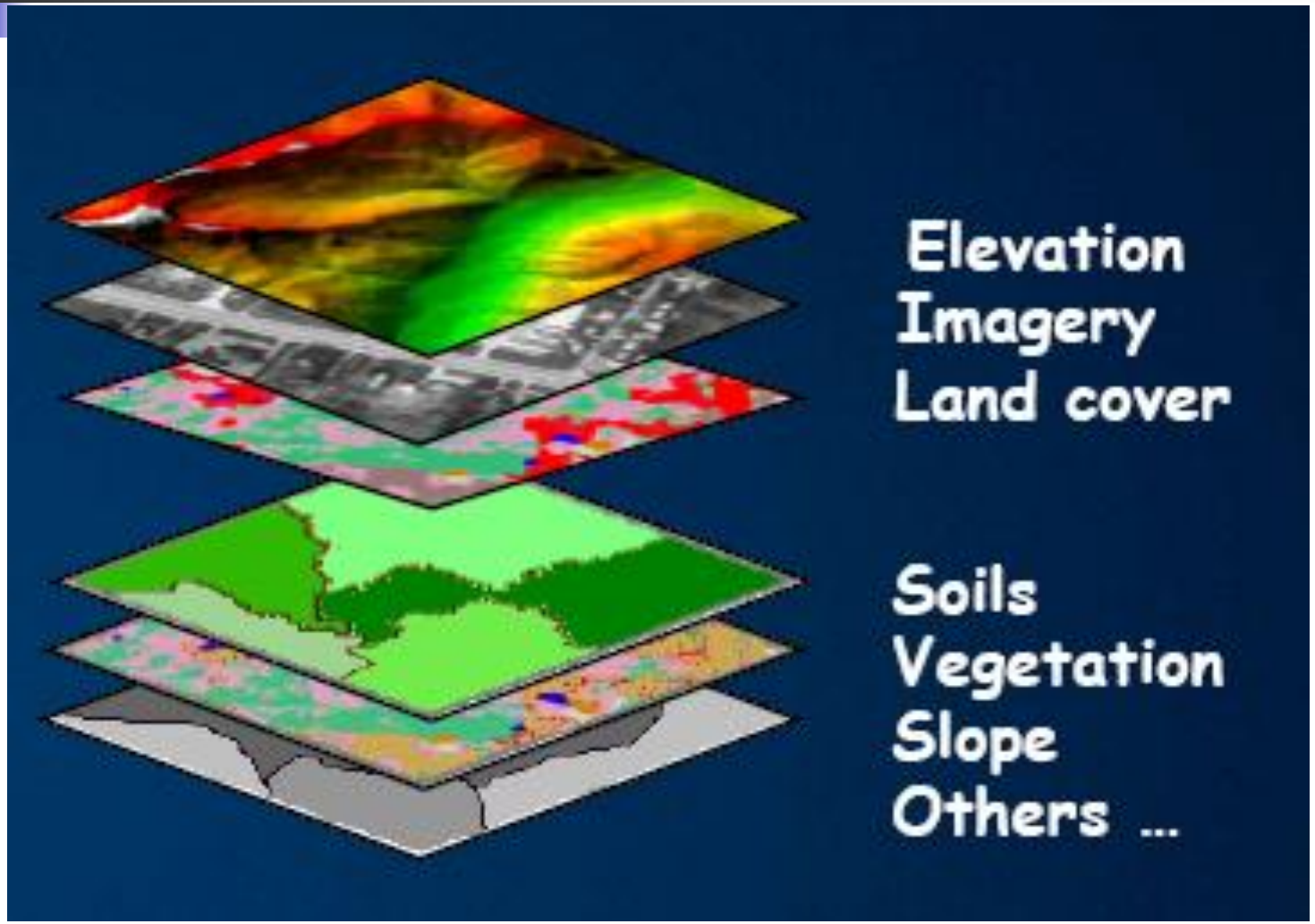
Map scale dependent



Vector data characteristics

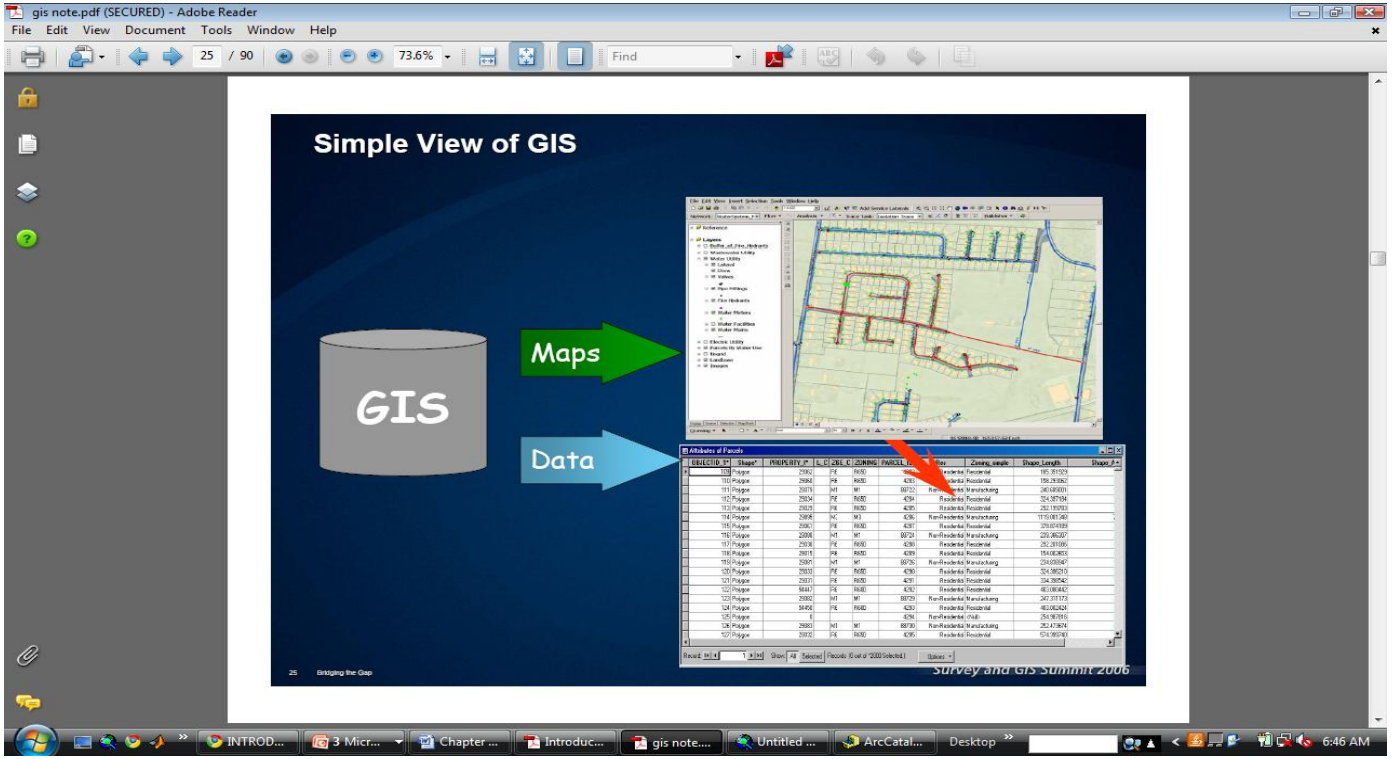
- One spatial feature, many attributes
- Does not fill space
- Graphics are composed of paths
- Relatively intuitive visualization
- The images can be scaled to be very large without losing quality
- produces smaller file size
- The file name is followed by .shp extension

Raste Data – cell based



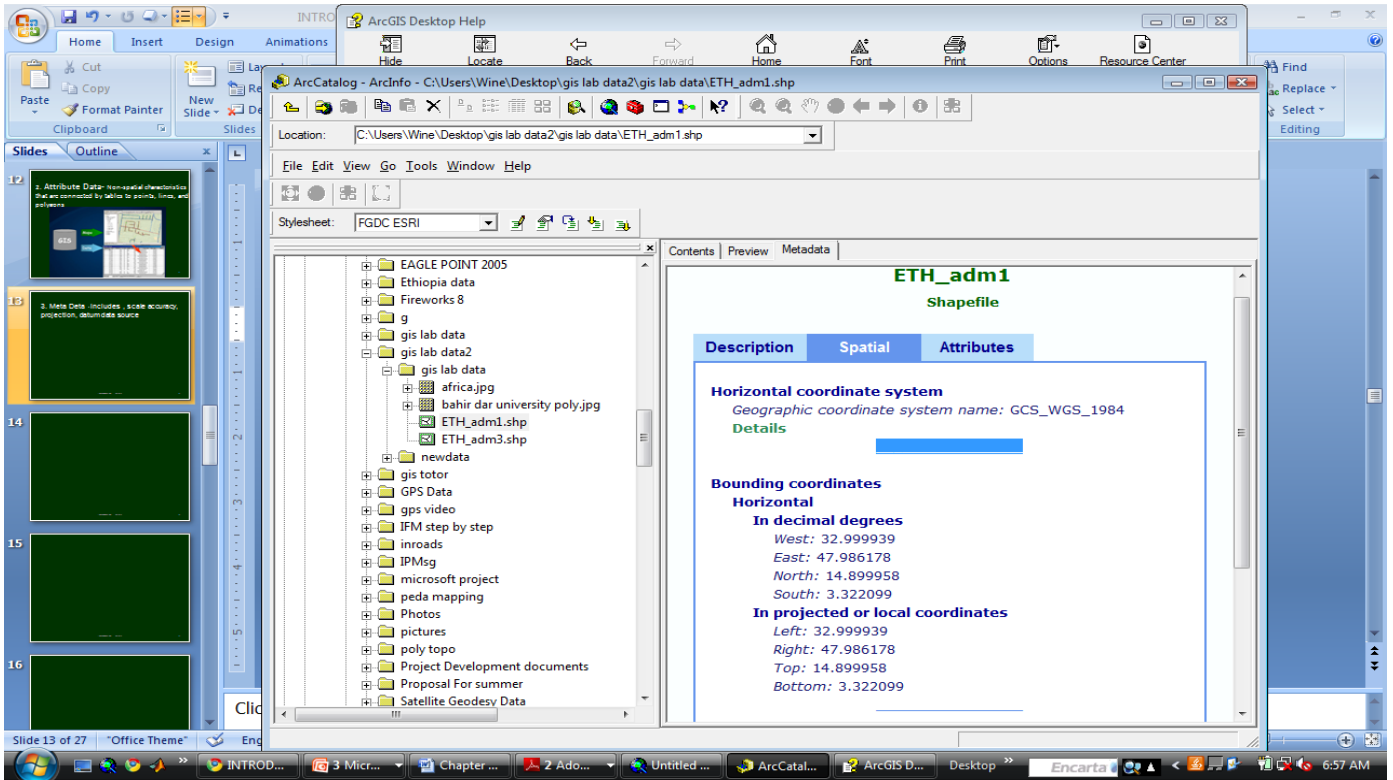
2. Attribute Data

Non-spatial characteristics that are connected by tables to points, lines, and polygons



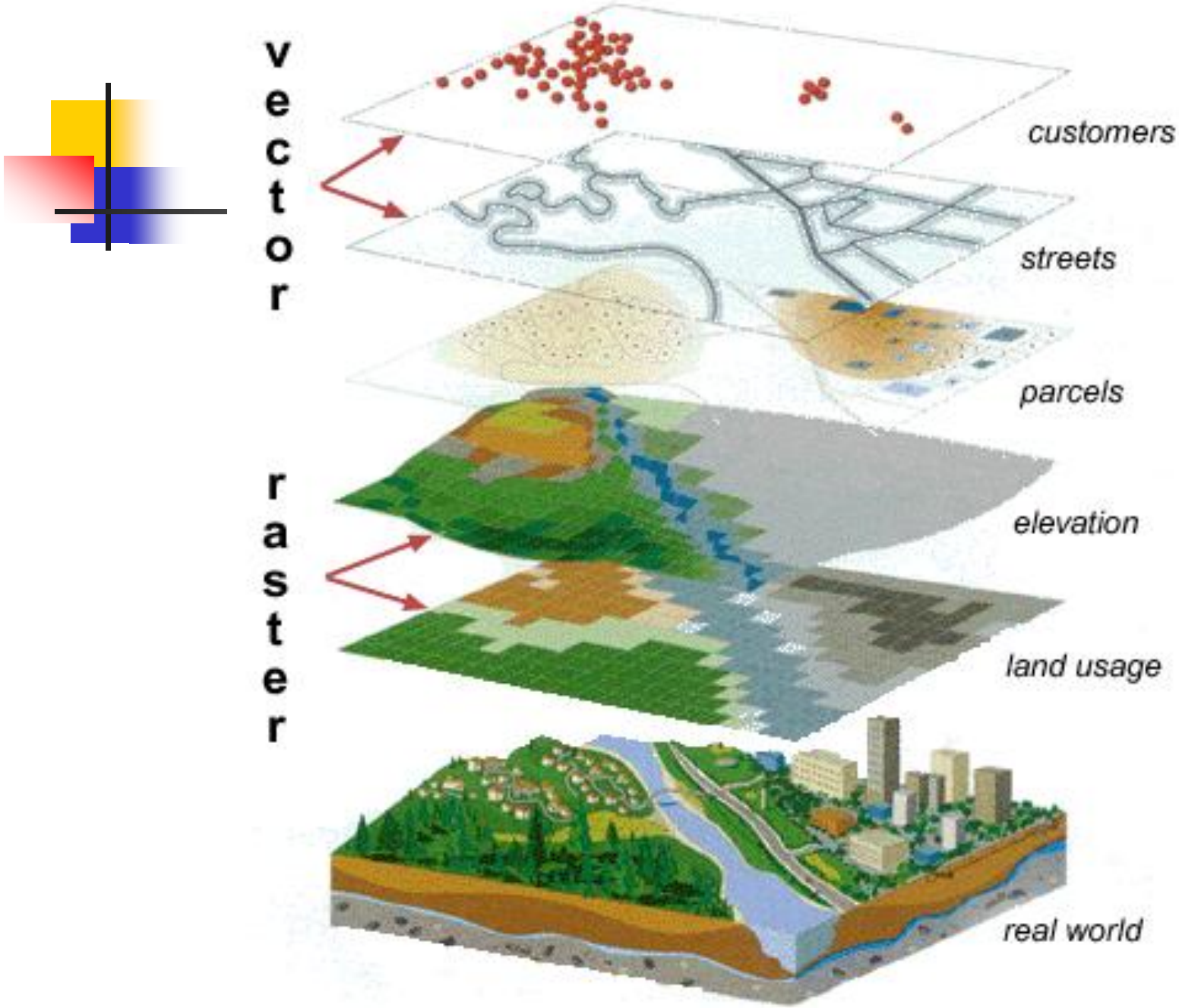
3. Meta Deta

- includes , scale accuracy, projection, datum data source



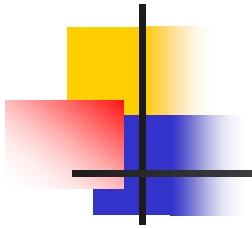
Data Layers

- the result of combining spatial & attribute data


vector
raster
customers
streets
parcels
elevation
land usage
real world

Data Sources

- Raster
  - Remote Sensing and satellite imagery
  - Digital Elevation Models (DEM) (Existed cell based data)
  - Raster Graphics
  - Rasterized Vector Features
  - Scanned imagery (aerial photographs & maps)



- Vector
  - Digitizing
  - Coordinate Geometry
  - Surveying
  - GPS
  - Vectorization of Raster Datasets

Hardcopy maps

Digital data

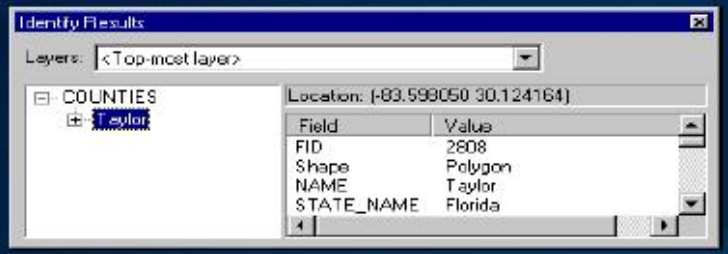
Coordinates

```
480585.5, 3769234.6
483194.1, 3768432.3
485285.8, 3768391.2
484327.4, 3768565.9
483874.7, 3769823.0
```

GPS

Query

- Identifying specific features

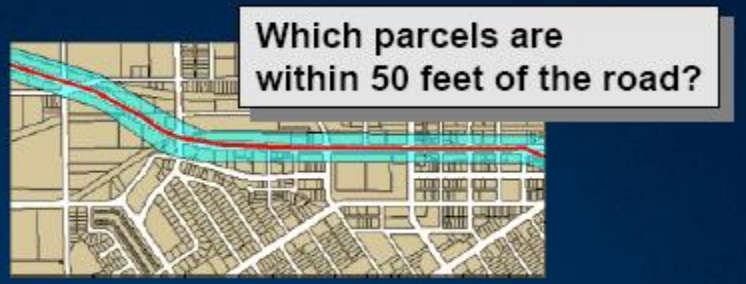


- Identifying features based on conditions

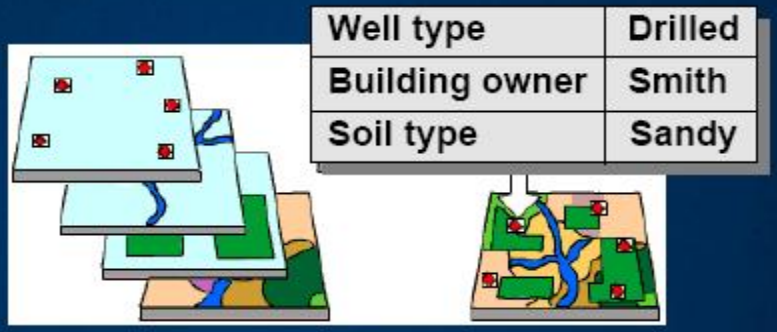
Florida counties with a population greater than 300,000

Analysis

Proximity

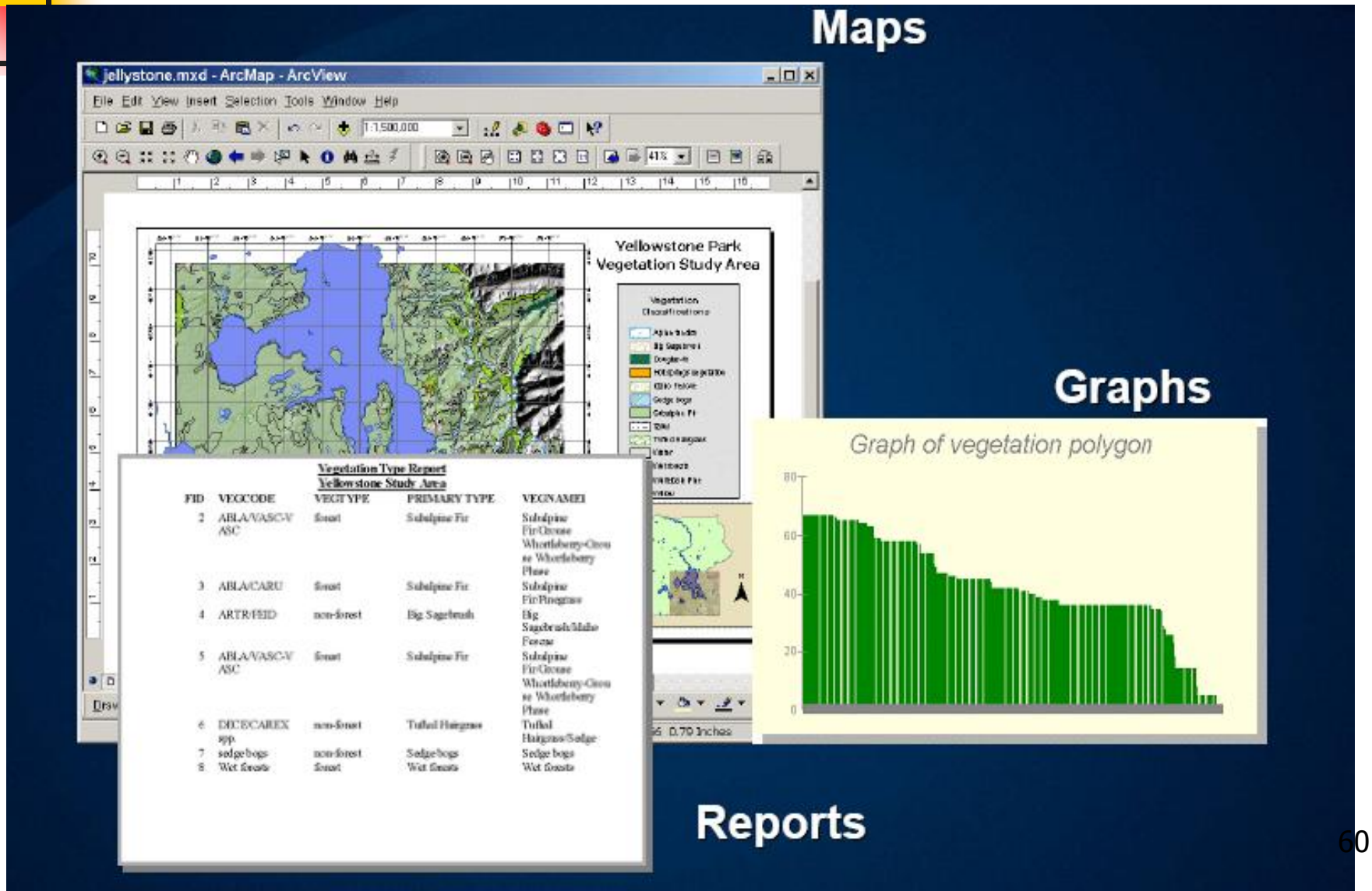


Overlay

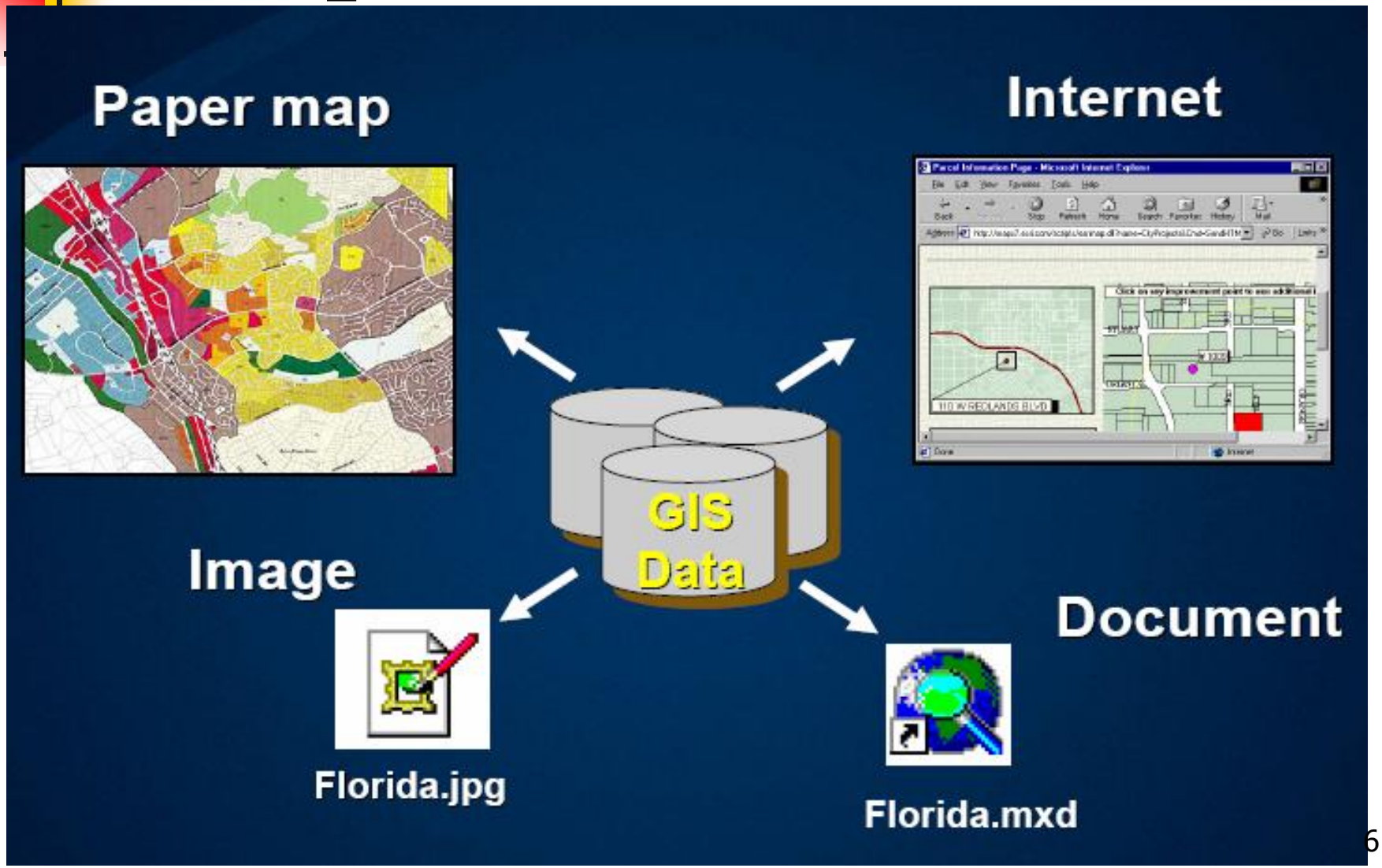


Network

Display type



Output


Paper map
Internet
GIS Data
Image
Florida.jpg
Document
Florida.mxd

Software

GIS software programs are usually either vector or raster based with capabilities in using both layer types.

Vector Based Software

- ArcView
- ArcGIS
- MapInfo

Raster Based Software

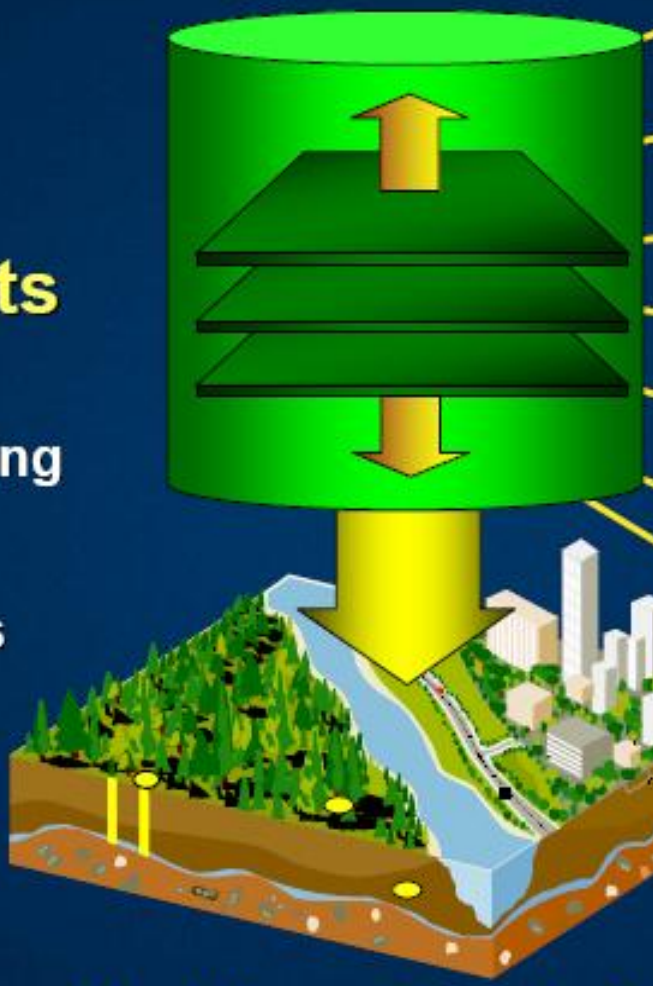
- Erdas Imagine
- IDRISI

Application of GIS

- Route selection (highway, pipeline)
- Hydrological modeling
- Land use planning (suitability map preparation)
- Natural resource mapping and management (forest, fire station)
- Route selection (highway, pipeline)
- Dispalying geographic distributionof events (e.g traffic accident in Africa)
- Mapping for urban planning and management
- Transportation planning
- Farmers (precision agriculture)
- Forestry

GIS Integrates All Types of Data

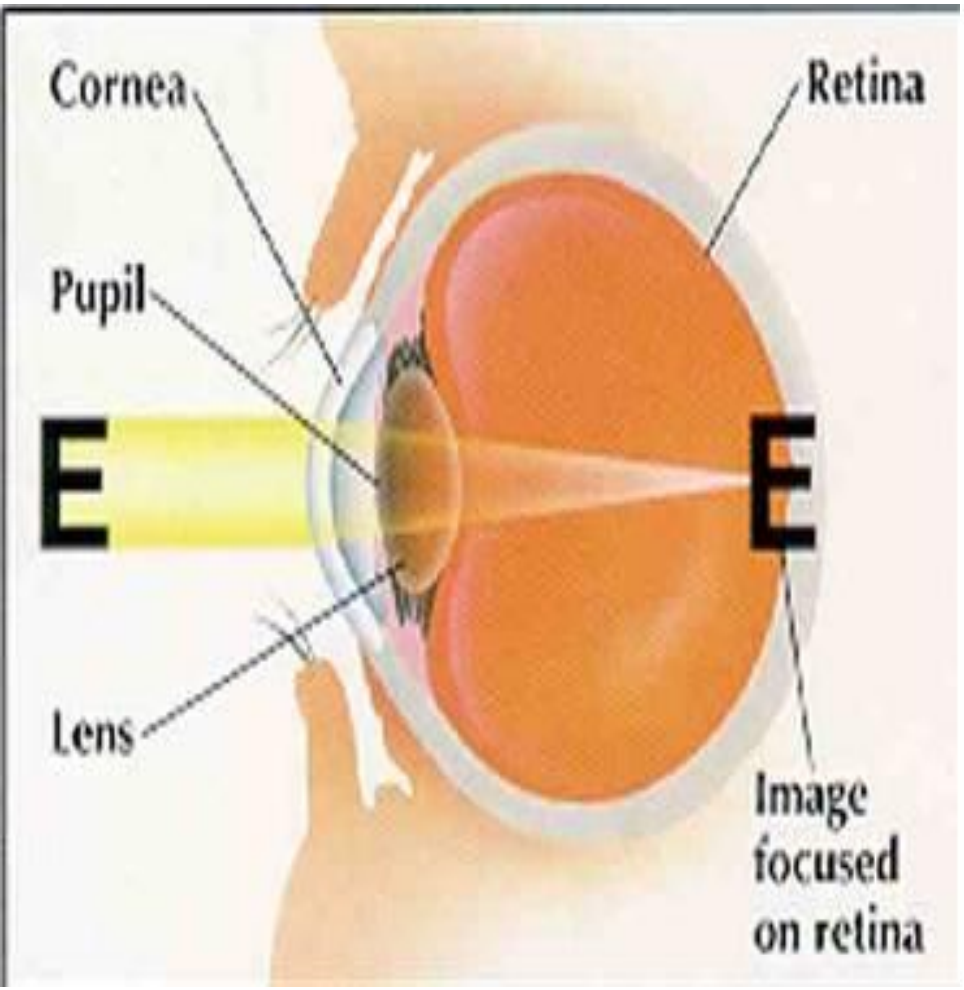
Geography is a "Key"



Key Concepts

- Georeferencing
- Digital Processing
- Map Overlay
- Spatial Analysis
- Visualization

. . . Integrating Disciplines, Organizations and Activities


Cornea
Retina
Pupil
E
E
Lens
Image
focused
on retina

Definition

- The science (and art) of acquiring information about an object, without entering in contact with it, by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.

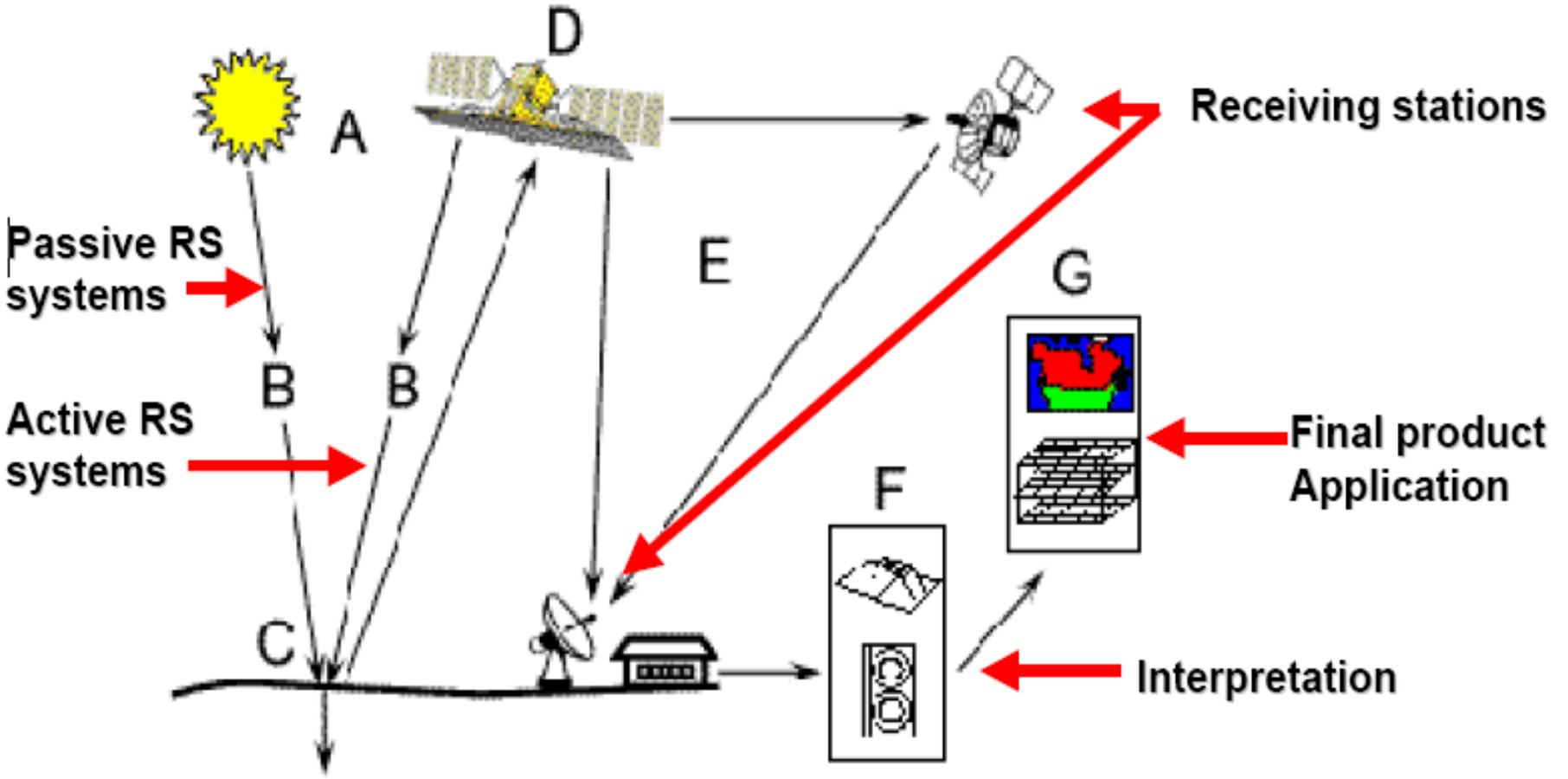
Introduction

- Collecting information about object, area or phenomena from distance without being in physical contact with them.
- Employs electromagnetic energy (such as light, heat, and microwave) as a means of detecting and measuring target characteristics.
- Aircraft and satellites are the common platforms used for remote sensing.
- Collection of data is usually carried out by highly sophisticated sensors

Introduction cont'd

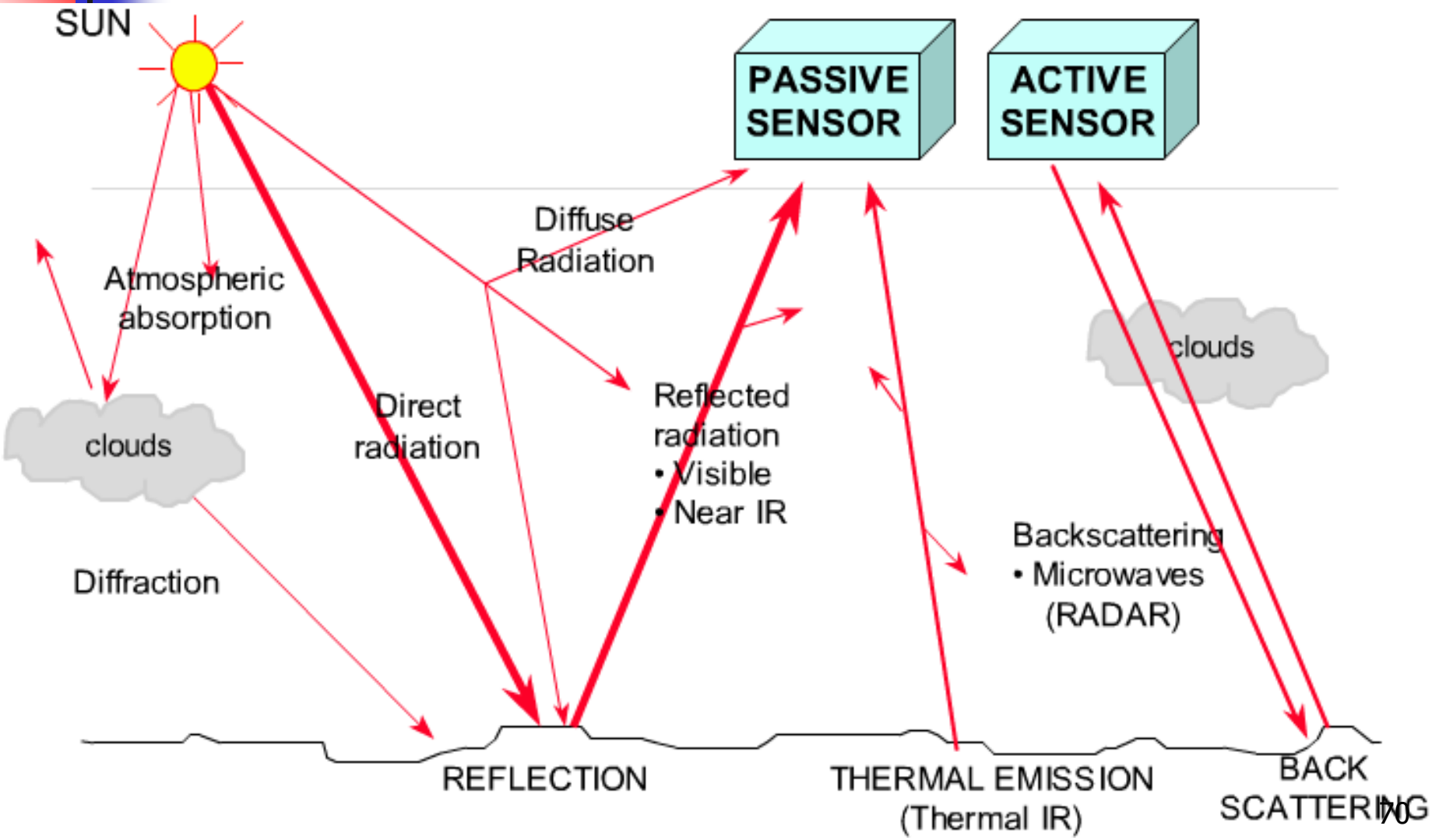
- The information carrier or communication link is the electromagnetic energy.
- Consists of wavelength intensity information by collecting the electromagnetic radiation leaving the object at the specific wavelength and measuring its intensity.
- Most of the RS methods make use of the reflected infrared bands, thermal infrared bands and microwave portion of the electromagnetic spectrum.

How it works?

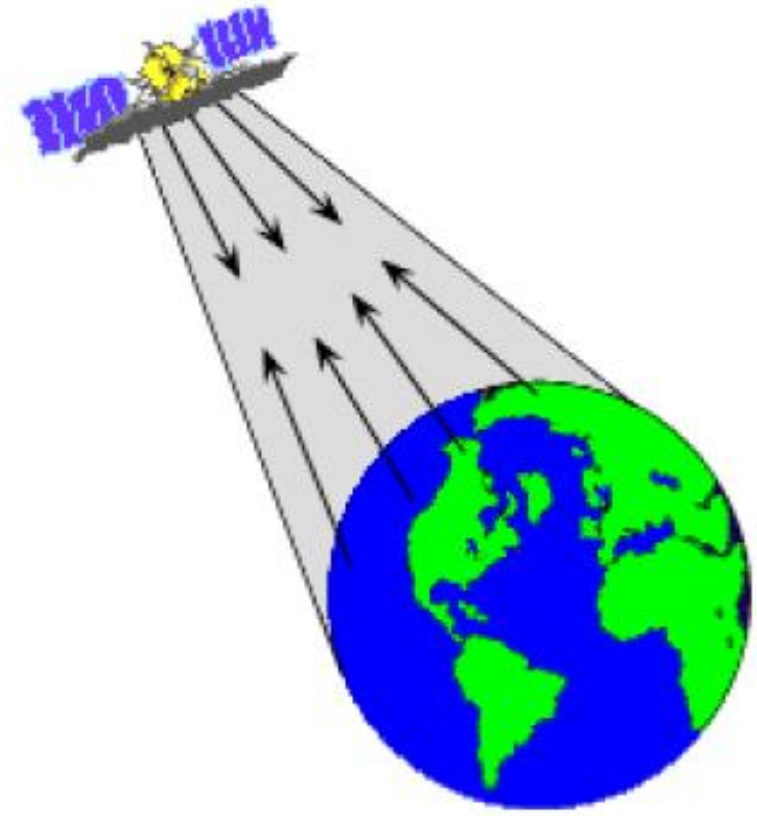


- Energy source: Passive/Active
- Atmosphere
- Target
- Recording devices
- Transmission/reception/processing
- Interpretation
- Application

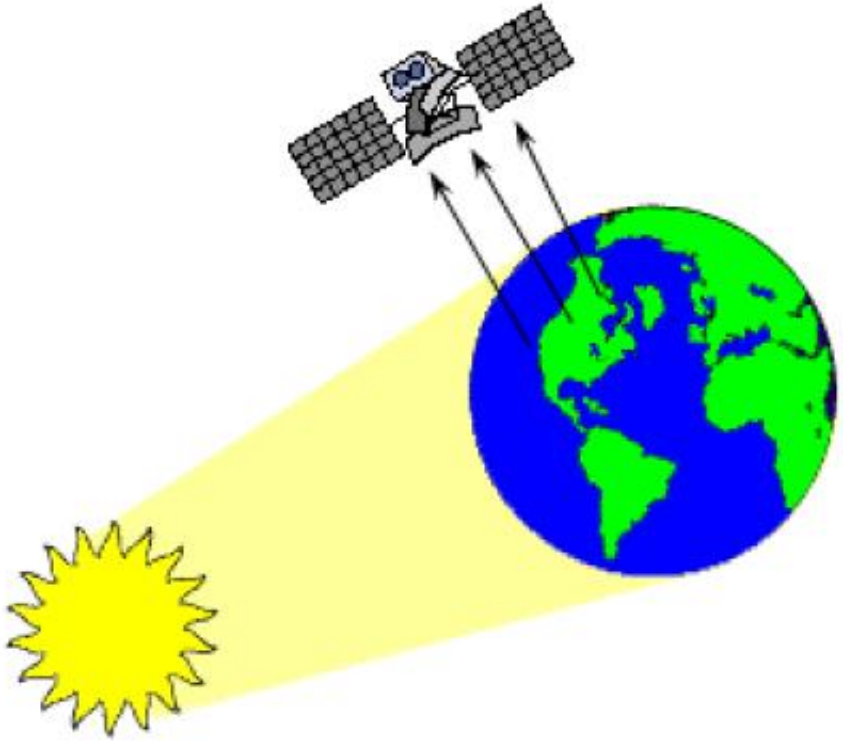
Classification of remote sensing



Active and Passive System



Active system



Passive system

Historical Sketch of Remote Sensing

- Invention of camera in the nineteenth century.
- During the First World War that free flying aircrafts were used in a remote sensing role
- Remote sensing for environmental assessment really became established after the Second World War
- Color photography came into existence after the invention of infrared films in 1950.
- From about 1960, remote sensing underwent a major development when it extended to space and sensors began to be placed in space.
- From 1970's started the new era of remote sensing. The first designated earth resources satellite was launched in July 1972, originally named ERTS-1 which is now referred as Landsat-1.
- The first Radar remote sensing satellite, SEASAT, was launched in 1978.

Idealized remote sensing system

An Idealized remote sensing system consists of the following stages:

- Energy source
- Propagation of energy through atmosphere
- Energy interaction with earth's surface features
- Airborne/space borne sensors receiving the reflected and emitted energy
- Transmission of data to earth station and generation of data
- Multiple-data users.

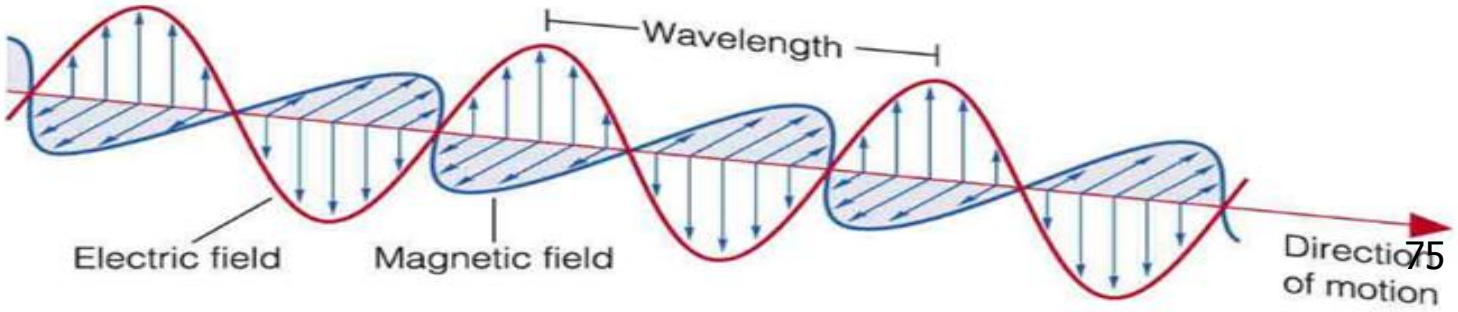
Principle of remote sensing

- Remote sensing employs electromagnetic energy and to a great extent relies on the interaction of electromagnetic energy with the matter (object).

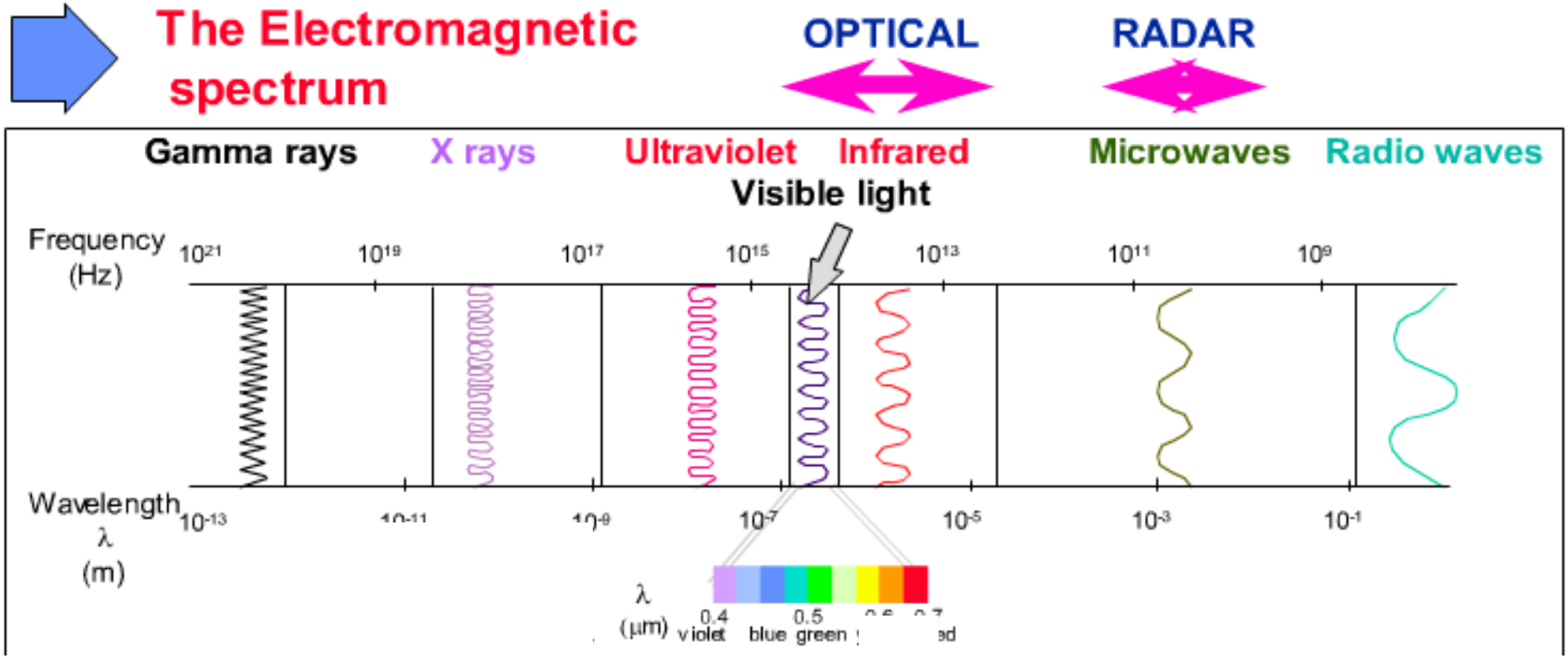
- It refers to the sensing of EM radiation, which is reflected, scattered or emitted from the object.

Electromagnetic Energy

- It is a form of energy that moves with the velocity of light ($3x10^8$ m/sec) in a harmonic pattern consisting of sinusoidal waves, equally and repetitively spaced in time.
- It has two fields (i) electrical field and ii) magnetic field, both being orthogonal to each other.

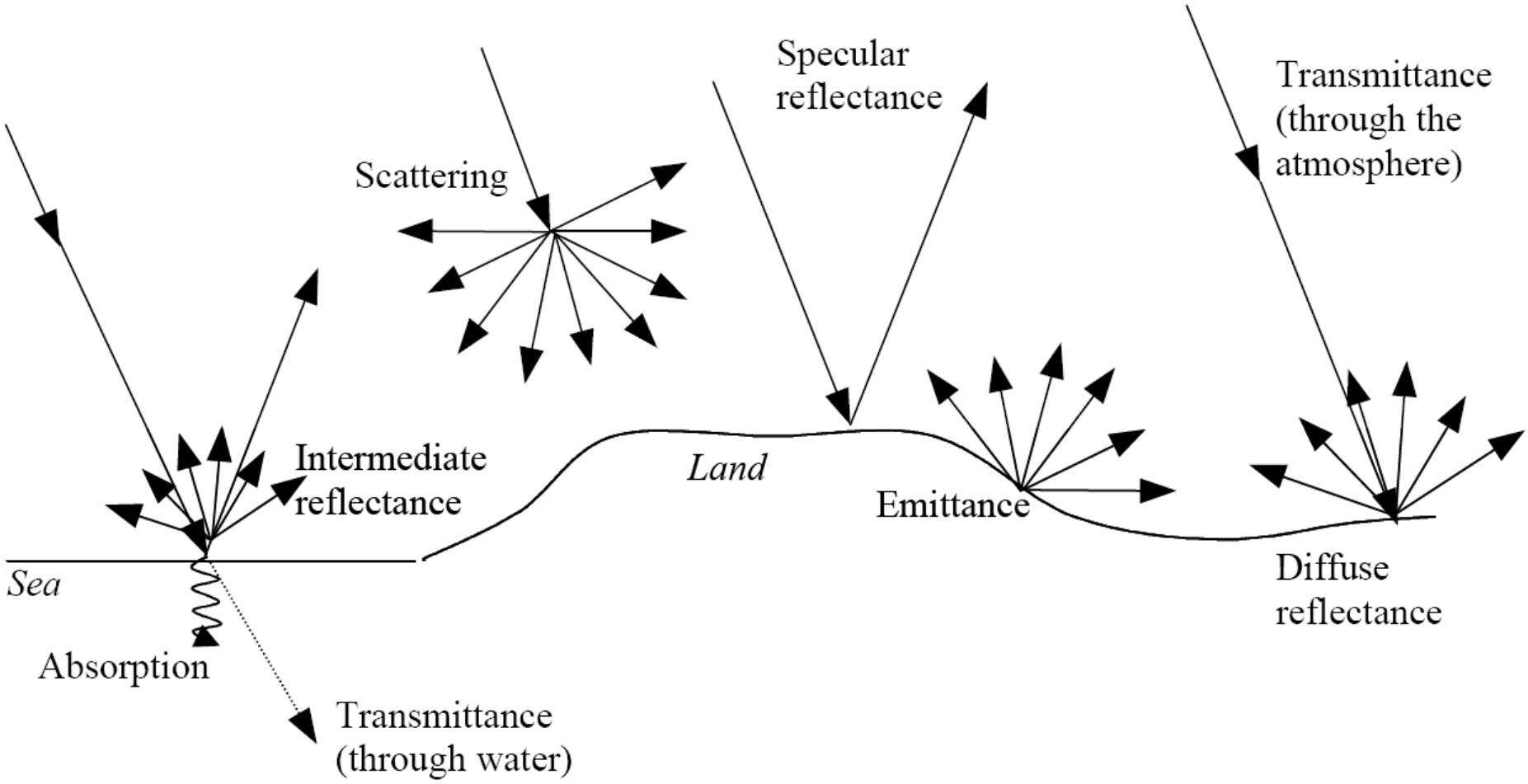


Electromagnetic Spectrum



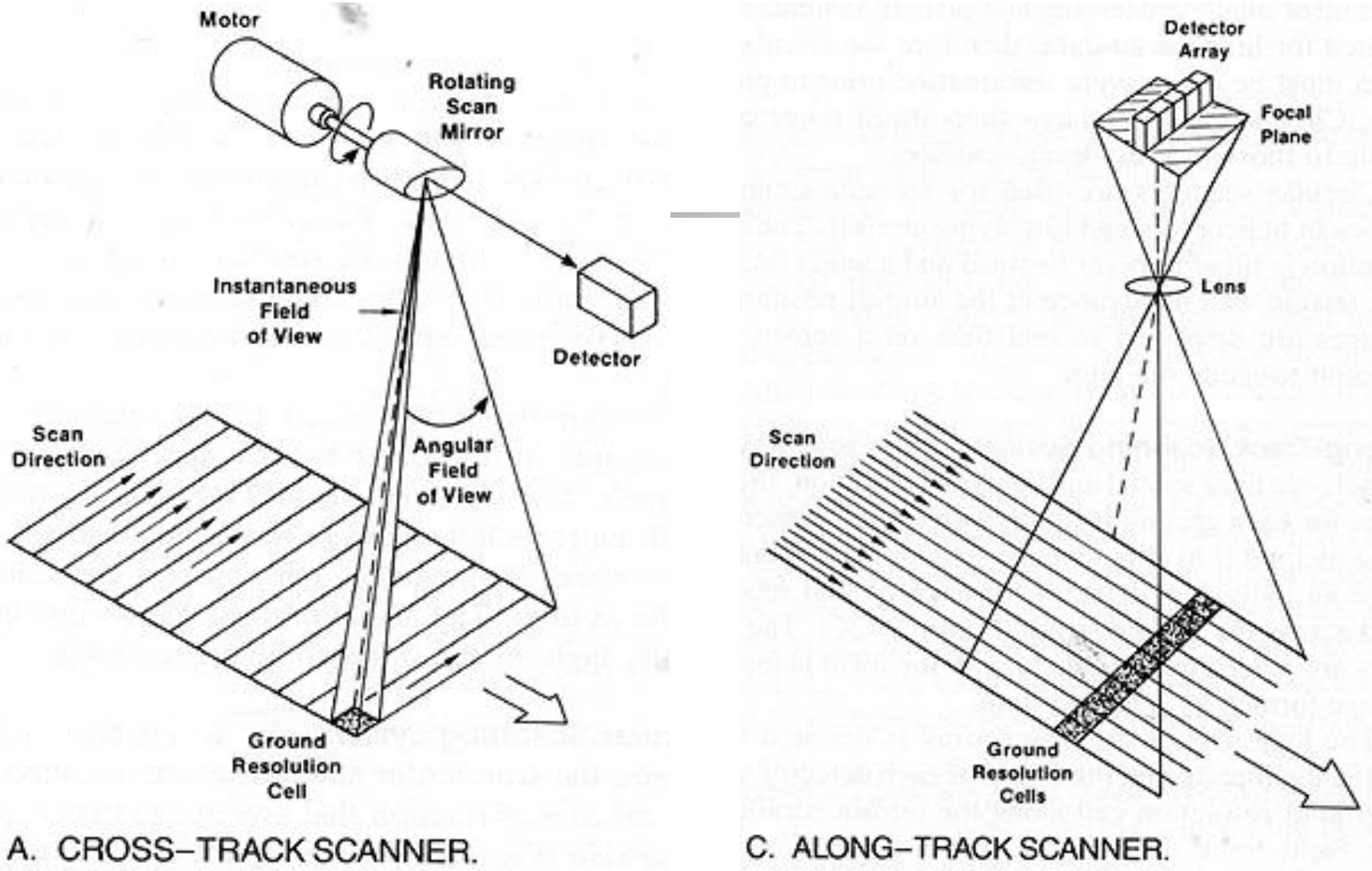
The electromagnetic spectrum may be defined as the ordering of the radiation according to wavelength, frequency, or energy.

Electromagnetic radiation interactions



Remote sensing Vs Photogrammetry

- A digital CCD (charge-coupled device) vs Analogue camera.
- Low resolution Vs High resolution
- Created line after line vs whole pictures taken once
- gather data all along vs only in the visible EMS
- Platform: Satellites vs Planes
- Both are affected by atmospheric disturbances. Thermal night, radar almost weather independent.



Scanning approaches for use of point sensor and line array

The systems

Three main types of sensors used

- **Optical (Visible/IR)**
- **Radar (Microwave)**
- **LiDAR (Mostly NIR)**

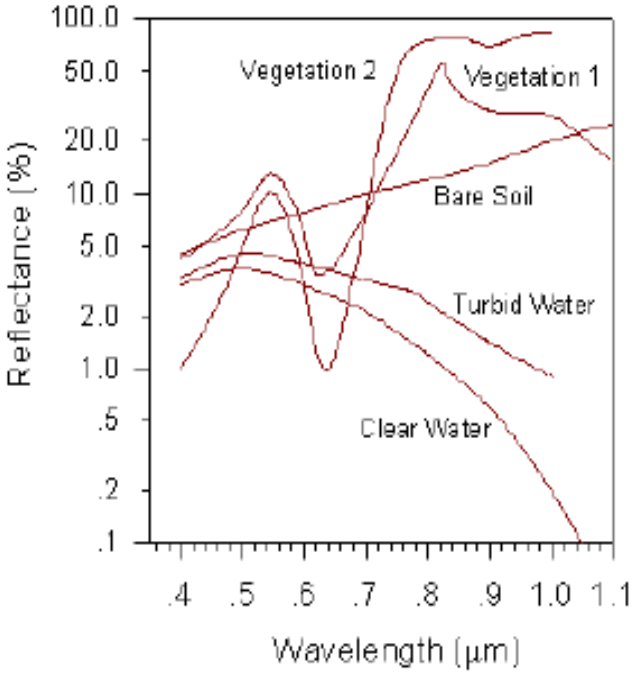
The systems: Optical

Optical record energy in the visible/IR portion of the electromagnetic radiation

Energy recorded in bands: multi/hyperspectral

Spectral signature: How reflects/absorbs radiation per wavelengths.

Can be plotted as a spectral curve.



Unique spectral signature of vegetation

Specific bands used alone, or as ratios to discriminate vegetations

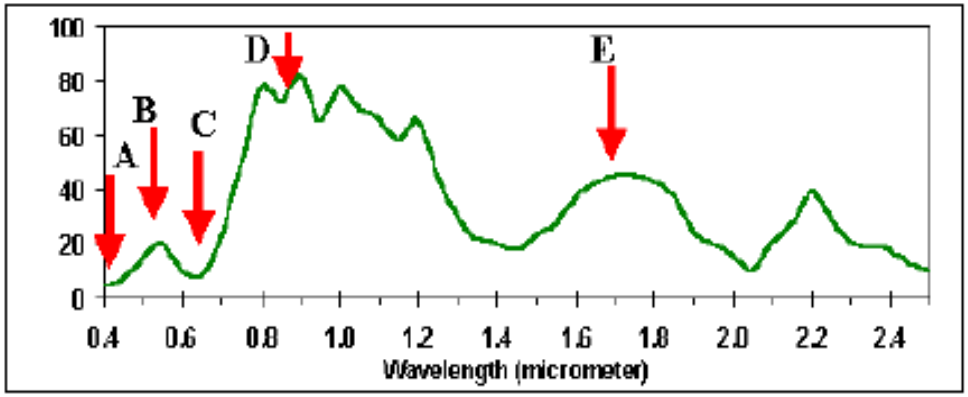
A: blue band

B: green band

C: red band

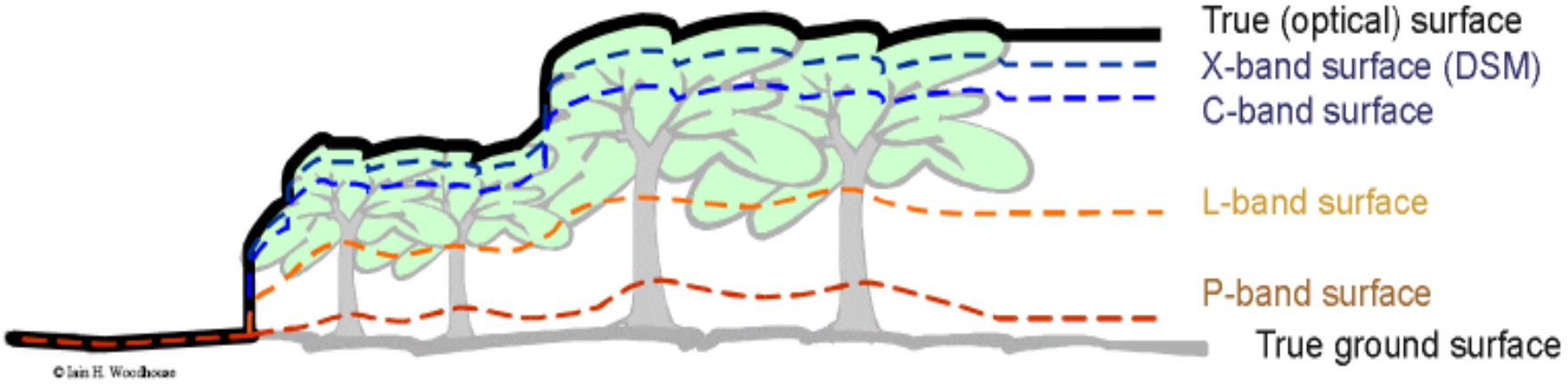
D: near IR band

E: short-wave IR band



The systems: Radar

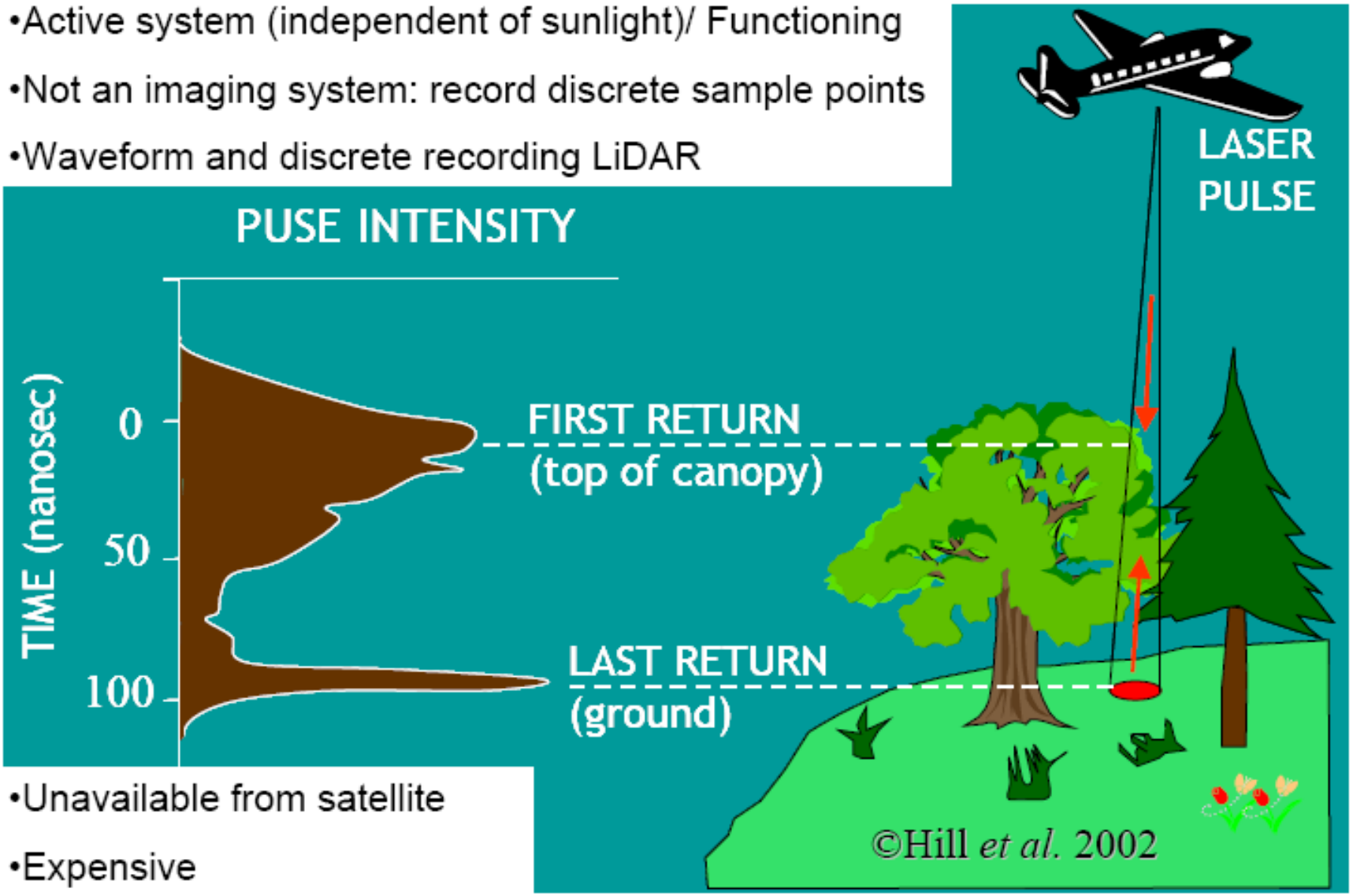
Advantages over optical: active system, not affected by atmosphere, penetrates the canopy (wavelength)



Radar Band	Frequency (GHz)	Wavelength (cm)
X	8.0 - 12.5	2.4 - 3.8
C	4.8 - 8.0	3.8 - 7.5
L	4.8 - 8.0	15 - 30
P	0.3 - 1.0	30 - 100

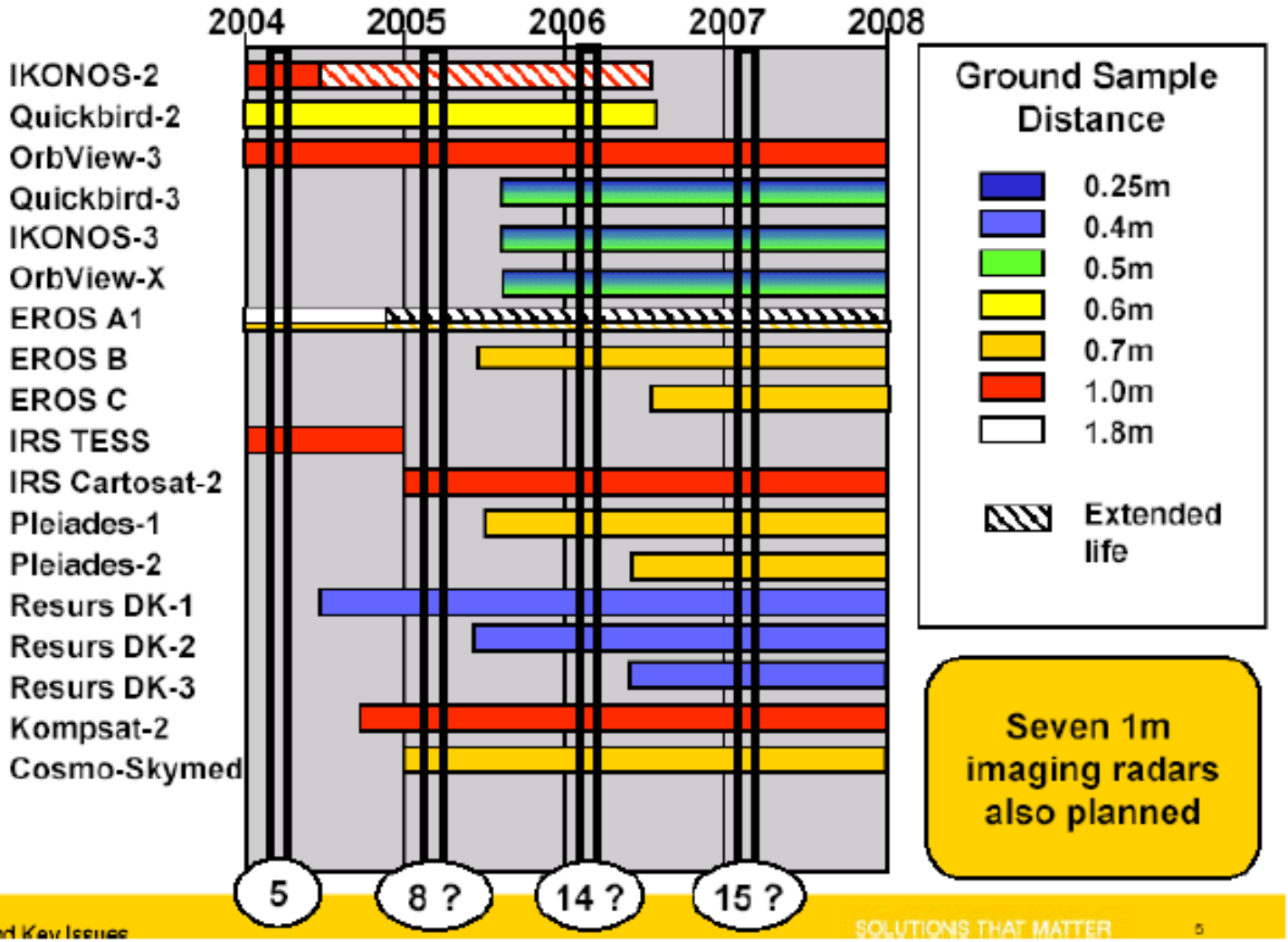
The systems: Lidar

- Light detection and ranging (Lidar)
- Active system (independent of sunlight)/ Functioning
- Not an imaging system: record discrete sample points
- Waveform and discrete recording LiDAR

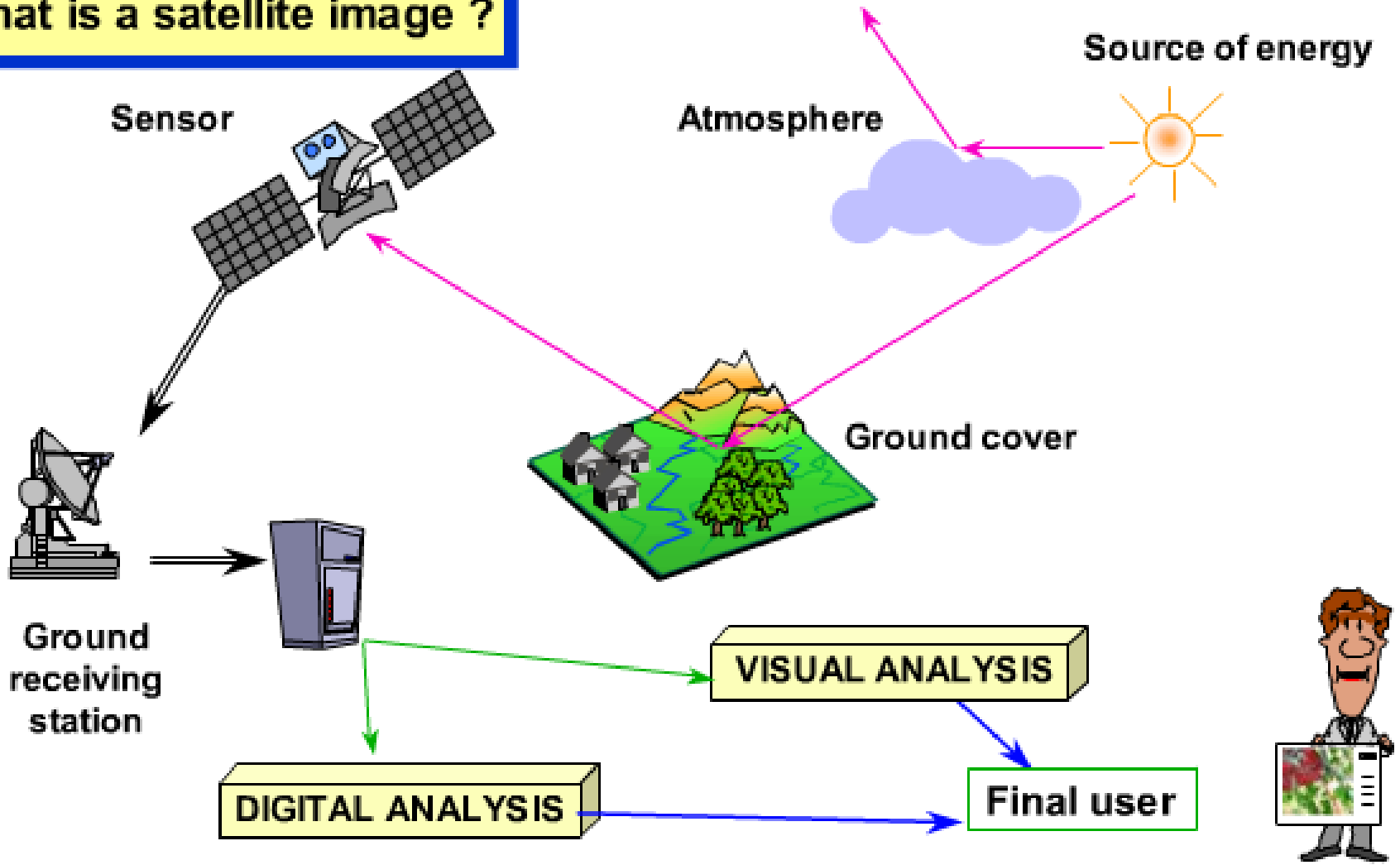


- Unavailable from satellite
- Expensive

New generation/Forthcoming sensors



What is a satellite image ?



The resolutions

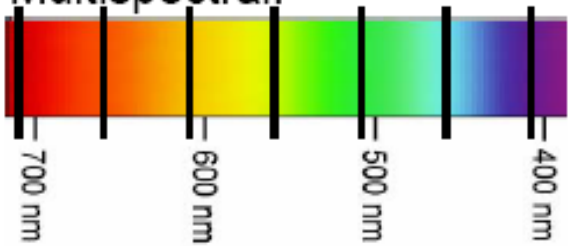
Spatial resolution: The ground area represented by each pixel in an image

High resolution

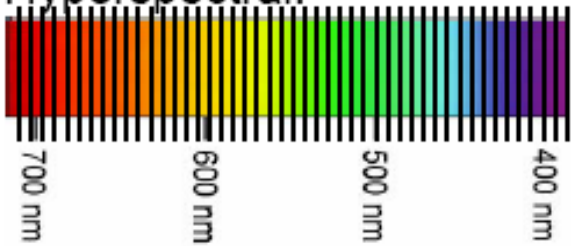
Low Resolution

Spectral resolution: Ability of sensor to separate EM into small intervals (bands)

Multispectral:



Hyperspectral:



Radiometric resolution: Ability to discriminate slight differences in energy

8-bit range

0 → 255

Temporal resolution: How often is the target sampled (orbital characteristics, swath width, flight campaigns)

Interest of Remote Sensing images

- Various Measurements: OPTICAL / RADAR
  Various bands (Visible, IR, Thermal ...)
- Various Scales : Global (Whole Earth)
  Regional (Several countries)
  National
  Local (a few kilometres)
- Various precision levels: Low resolution (1 to 5 km per pixel)
  High resolution (10 to 30 m)
  Very High resolution (approx. 1m)
- Various Repetitivities: Time between 2 acquisitions :
  from 1/2 hour to more than 20 days

Various Applications !

Geology - Agriculture - Meteorology
Cartography - Oceanography
Environmental and resource monitoring
Urban and land management...

Application of remote sensing: Mapping

- **Planimetry:** Ground surveying techniques can be used to meet high accuracy requirements, but limitations include cost effectiveness, and difficulties in attempting to map large, or remote areas.
- **Digital elevation models (DEM's):** Generating DEMs from remotely sensed data can be cost effective and efficient. Two primary methods are 1. Stereogrammetry techniques using airphotos (photogrammetry), VIR imagery, or radar data (radargrammetry), and 2. Radar interferometry.
- **Baseline thematic mapping / topographic mapping:**