Introduction to GNSS

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Layout

Satellites

- GNSS Introduction
- Composition
- Triangulation
- Orbits
- Geodetic Datum (NMEA)

GPS

- Space Segment
- Control Segment
- User Segment
- Performance
- Error sources
- Real Time Applications

Layout

Augmentation Systems

- Introduction
- GBAS
- SBAS
- Overview

Remote Sensing

- Sensors
- Working principle
  - Spectral Bandwidth
  - Classification
  - Resolution
  - Device examples
  - Image examples
- Overview

Layout

Geographic Information System (GIS)

- Definition
- Components
- Principle
- Data types

GNSS

Satellites

- Composition
- Orbits
- Triangulation
- Geodetic Datum (NMEA)

GNSS. Introduction

The Global Navigation Satellite System (GNSS) is a constellation of orbiting satellites together with ground based equipment enabling a user to determine his position, with respect to a given coordinate system, using signal transmitted by satellites.

GNSS

- <u>Global Constellation</u>
  - GPS USA
  - GLONASS, Russia
  - Galileo, Europe
  - BeiDou (COMPASS), China
- <u>Regional Constellation</u>
  - QZSS, Japan
  - NAVIC (IRNSS), India

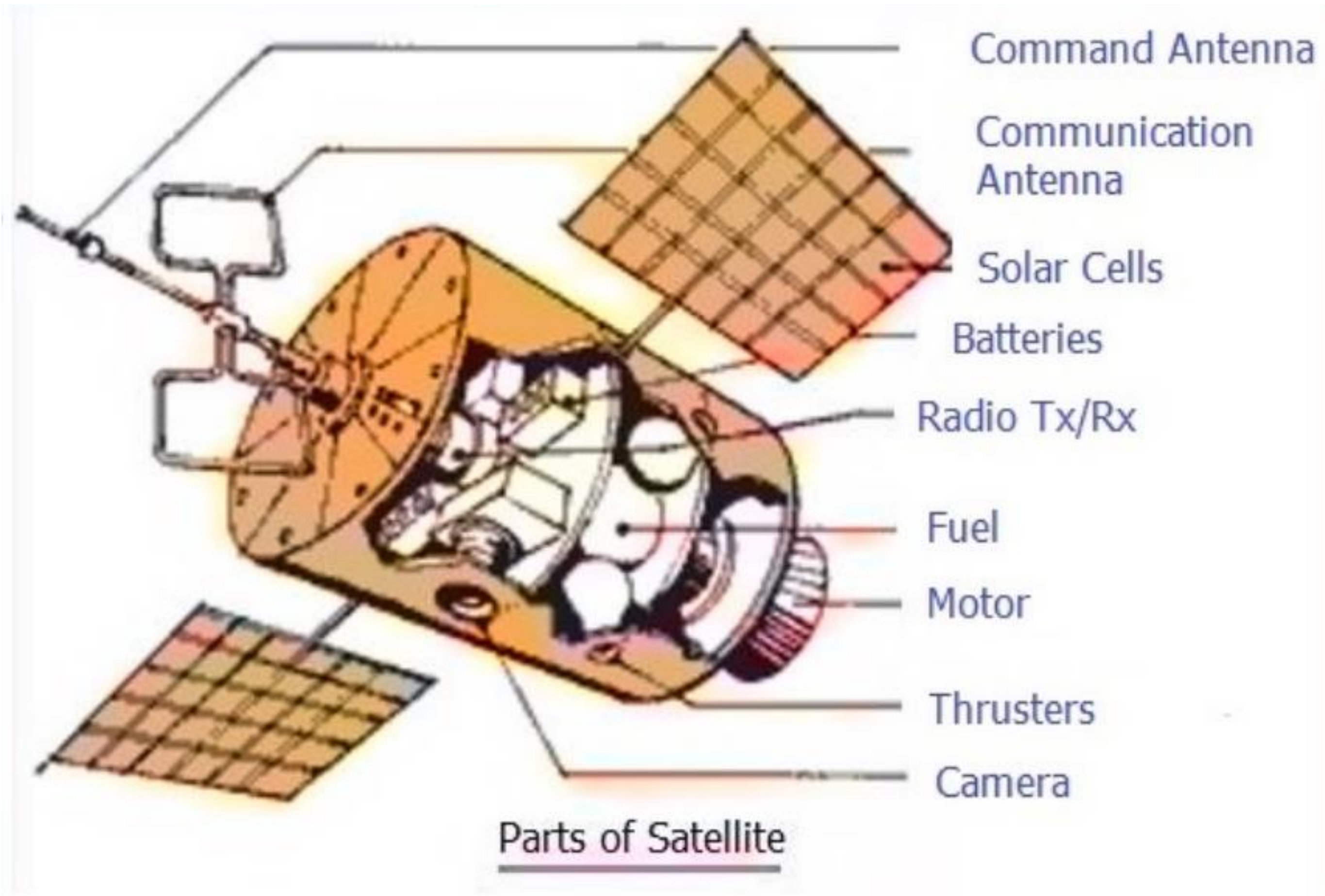
By integrating GNSS with other technologies, the Agriculture industry can benefit from:

- Improving the monitoring of the distribution and dilution of chemicals.
- Improving parcel yield from customized treatment.
- More efficient property management

Satellites

"A satellite is a device sent up into space to travel around the earth, used for collecting information or communicating by radio, television, etc."

Satellite. Composition



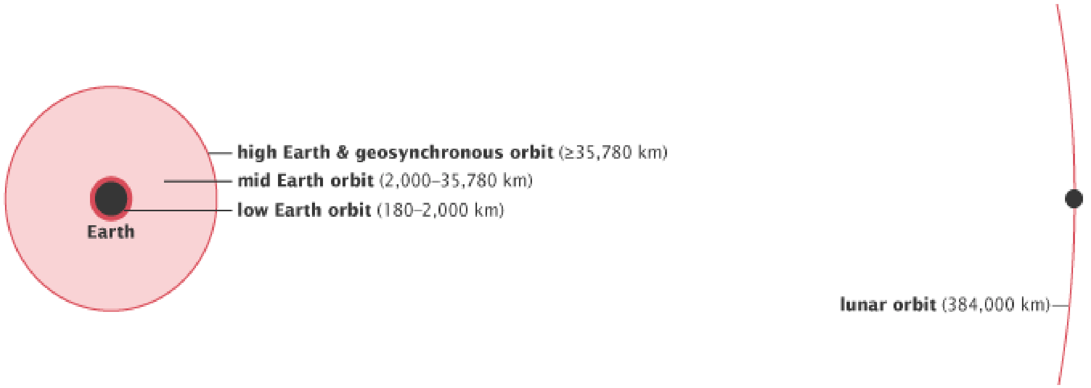
Satellites. Orbits

Low Earth orbit (LEO) → below 2000km [remote sensing, military purposes and for human spaceflight]

Medium Earth orbit (MEO)→ from 2000km to 35786 km [navigation, communication, and geodetic/space environment science]

Geostationary Orbit (GEO) → circles the Earth above the equator with inclination 0, it is seen as a fixed point by an earth viewer [weather observation, oceanography and atmospheric tracking]

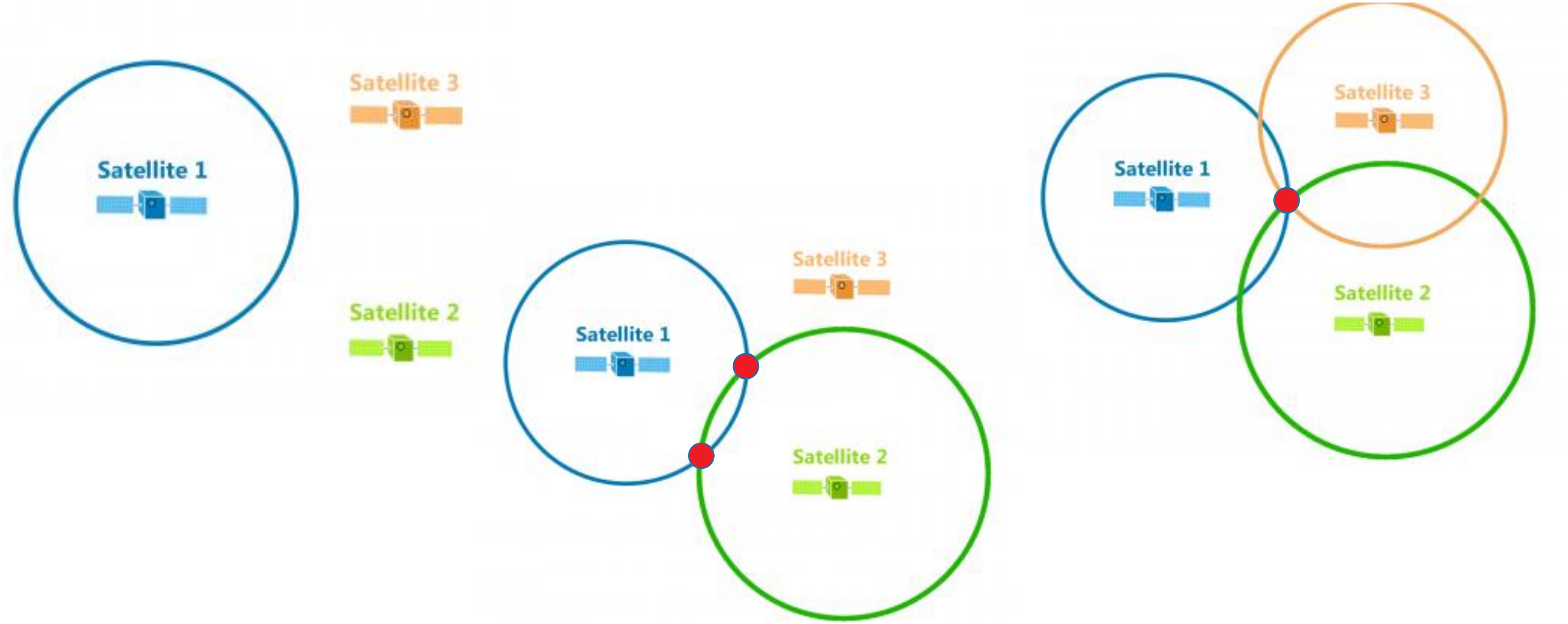
High Earth Orbit (HEO) → Above 35786 km [Comunicación]



Triangulaiton

Working principle.

- Each satellite give you a distance.
- In 2 dimensions 3 satellites are needed to obtain a common point.

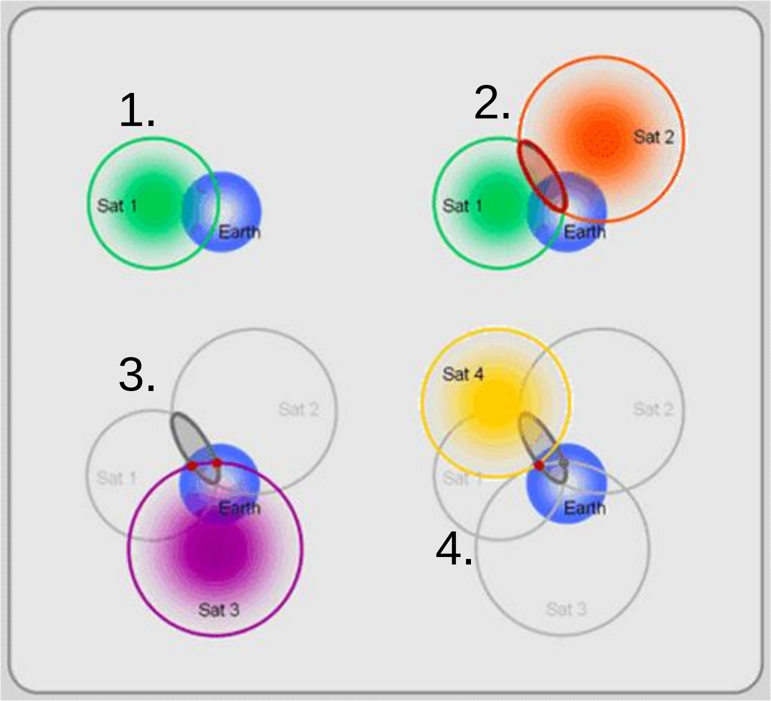


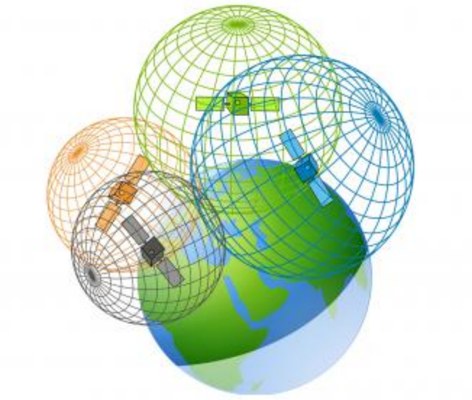
Trilateration

Working principle.

Trilateration use the same principle than triangulation in 3 dimensions:

1. User is somewhere on a sphere.
2. User is somewhere in the intersection circle.
3. User can be at either both points
4. User in the red point

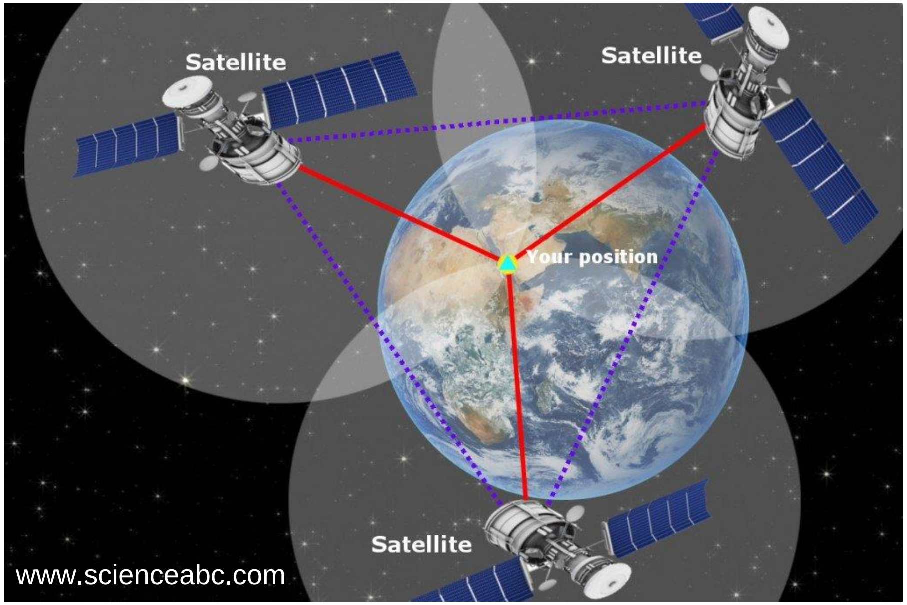




Trilateration

Working principle.

The 4th satellite would therefore be necessary, because the intersection of 3 spheres gives 2 points. However, it can be dispensed with because only one of the two points is geometrically coherent. And so, there would still be a possibility to eliminate. Three satellites will determine latitude, longitude, and height. The fourth one synchronizes the receiver's internal clock.



$$\rho^{(s)} = \sqrt{(x^{(s)} - x)^2 + (y^{(s)} - y)^2 + (z^{(s)} - z)^2} + c\delta t_u - c\delta t^{(s)} + \epsilon$$

$p^{(s)}$=($x^{(s)}$,$y^{(s)}$,$z^{(s)}$)= satellites position
(x,y,z)=unkown user position
δt= clock bias (user and satellite)
Є = ionosphere and atmosphere delays.

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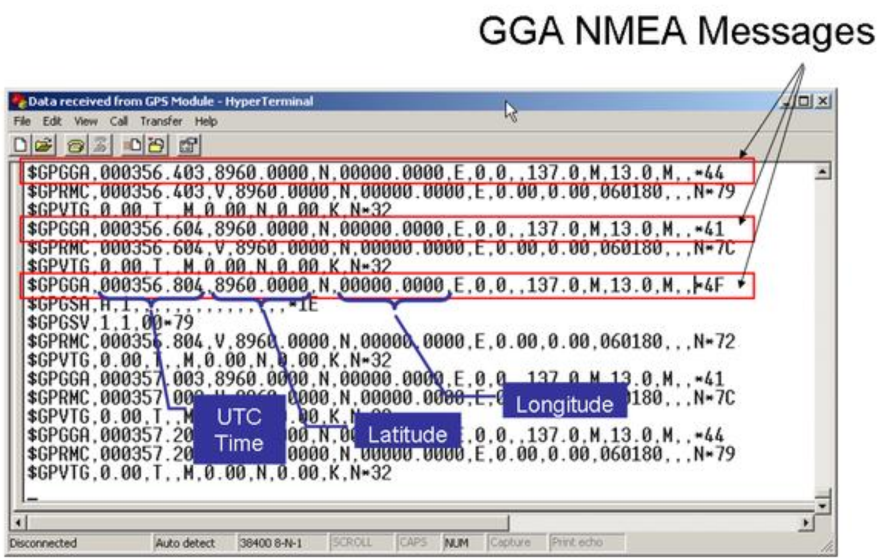
Satellites. NMEA

What do you see in your GPS receiver?
To read the messages, an standard have been designed: NMEA.
National Marine Electronics Association was developed by marine equipments, GPS is defined within this specification.



NMEA interpretation

https://www.gpsinformation.org/dale/nmea.htm

Longitude (11º 31.000 E)

Altitude [m]

Checksum

Fix Quality*

$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,*47

Hour UTC (12:35:19)

Number of satellites

Height of geoid [m]

Name sentence

Latitude (48º 07,038' N)

HDOP (Accuracy)

Satellites. Geodetic datum

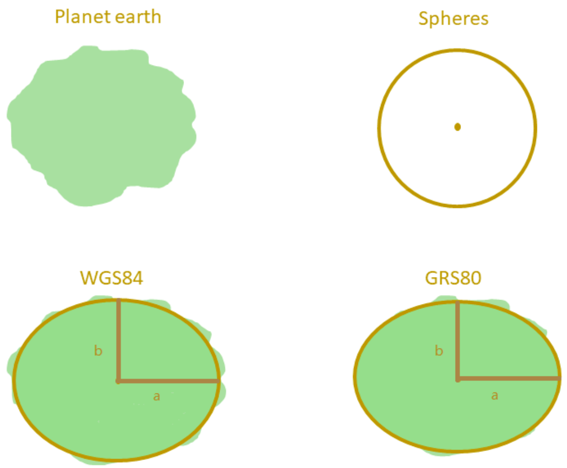
Geodetic datum is basically an earth model in order to locate places in his surface, defining the shape and size of our planet. The most known are:

- World Geodetic System (WGS) → WGS84
- Geodetic Reference System (GRS)→GRS80

Each datum includes, among others:

- ➢ Coordiantes system
- ➢ Earth Gravitational Model (EGM)
- ➢ World Magnetic Model (WMM)

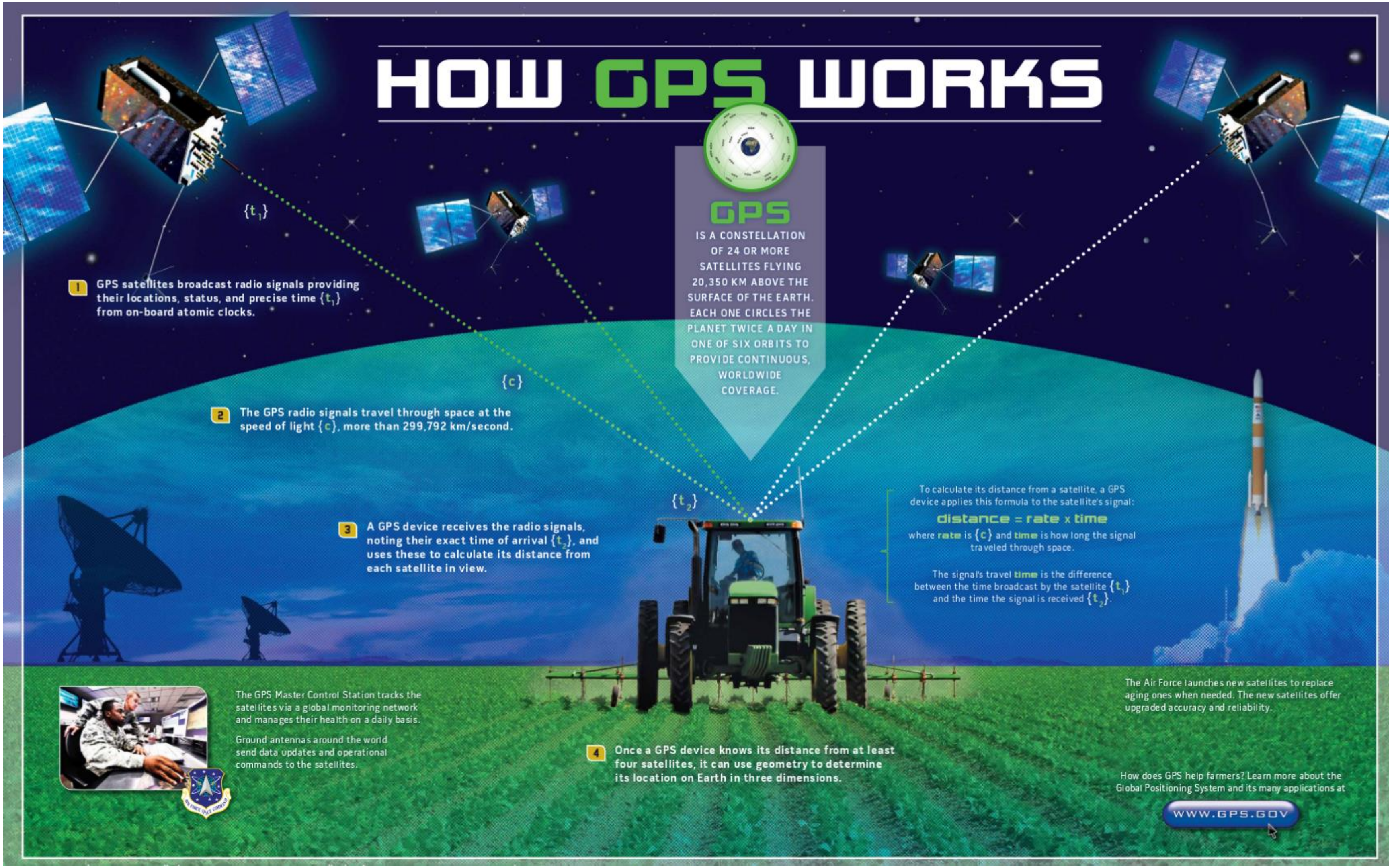
http://support.virtual-surveyor.com



Layout

- **GPS**
  - Space Segment
  - Control Segment
  - User Segment
  - Performance
  - Error sources
  - Real Time Applications

GNSS Example: GPS

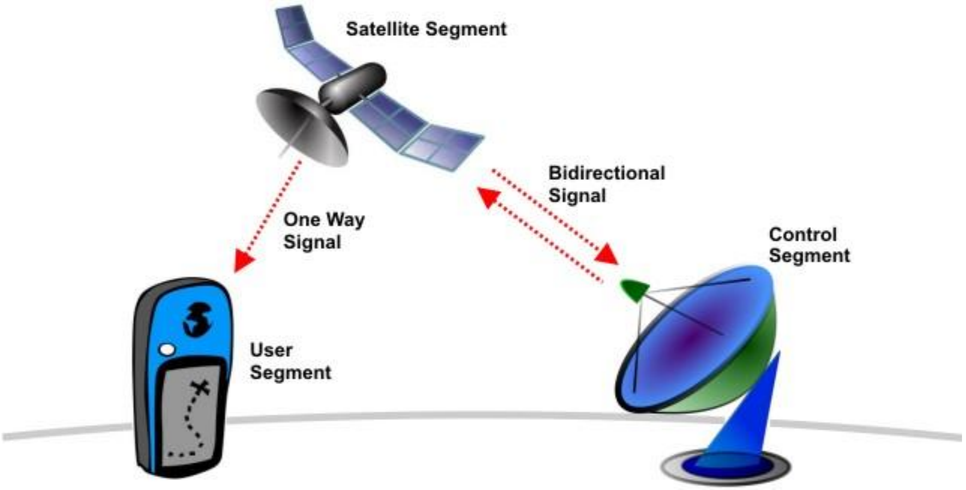


Global Positioning Systems(GPS)

U.S.-owned utility to provides users with positioning, navigation, and timing (PNT) services.

Composed by:

- Space Segment
- Control Segment
- User Segment



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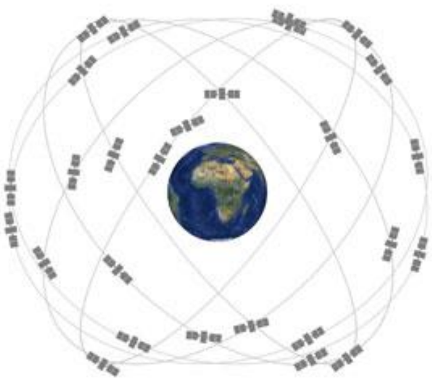
GPS. Space Segment

- Medium Earth Orbit (MEO) ~20.200km

1993
24 satellites

2011
Exapandable 24
27 satellites

2019
31 satellites

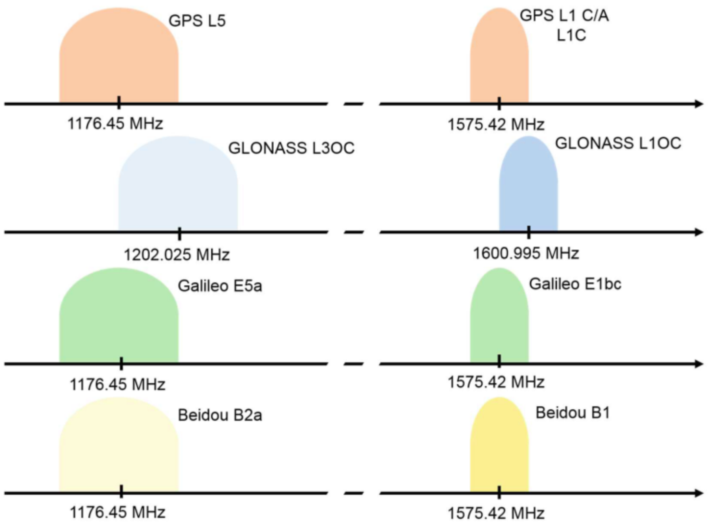


GPS. Space Segment

Frecuencies:

- Legacy signal (initial)
  - L1 C/A (coarse/acquisition)

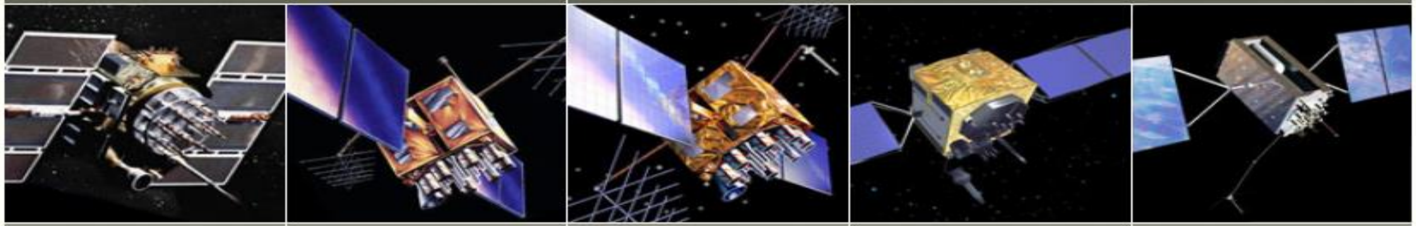
- Modernized signals
  - L2C (Military only, 1227MHz, 2005)
  - L5C (Civilian, 1176,45MHz, 2010)
  - L1C (Military and civilian, 1575MHz)



Navigation messages, what's include:

- The GPS date and time and the satellite's status.
- The ephemeris: precise orbital information for the transmitting satellite.
- The almanac (slice of ephemerides): status and low-resolution orbital information for every satellite.

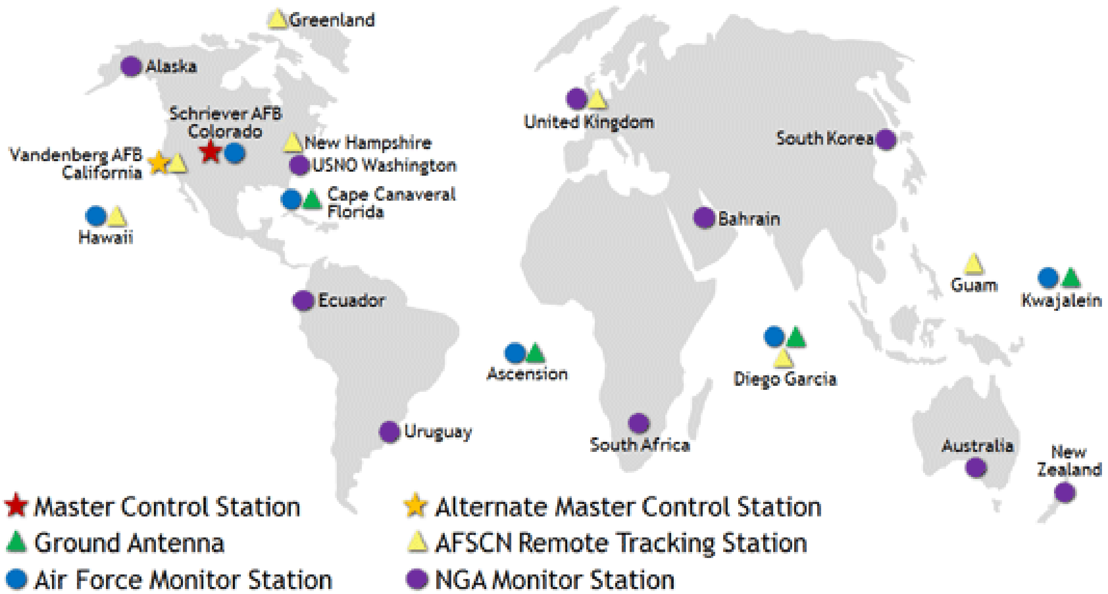
GPS. Space Segment



LEGACY SATELLITES		MODERNIZED SATELLITES		
BLOCK IIA	BLOCK IIR	BLOCK IIR-M	BLOCK IIF	GPS III/IIIF
1 operational	11 operational	7 operational	12 operational	1 in checkout
▪ Coarse Acquisition (C/A) code on L1 frequency for civil users ▪ Precise P(Y) code on L1 & L2 frequencies for military users ▪ 7.5-year design lifespan ▪ Launched in 1990-1997	▪ C/A code on L1 ▪ P(Y) code on L1 & L2 ▪ On-board clock monitoring ▪ 7.5-year design lifespan ▪ Launched in 1997-2004 LEARN MORE ABOUT GPS IIR AT AF.MIL	▪ All legacy signals ▪ 2nd civil signal on L2 (L2C) LEARN MORE ▪ New military M code signals for enhanced jam resistance ▪ Flexible power levels for military signals ▪ 7.5-year design lifespan ▪ Launched in 2005-2009 LEARN MORE ABOUT GPS IIR-M AT AF.MIL	▪ All Block IIR-M signals ▪ 3rd civil signal on L5 frequency (L5) LEARN MORE ▪ Advanced atomic clocks ▪ Improved accuracy, signal strength, and quality ▪ 12-year design lifespan ▪ Launched in 2010-2016 LEARN MORE ABOUT GPS IIF AT AF.MIL	▪ All Block IIF signals ▪ 4th civil signal on L1 (L1C) LEARN MORE ▪ Enhanced signal reliability, accuracy, and integrity ▪ No Selective Availability LEARN MORE ▪ 15-year design lifespan ▪ IIIF: laser reflectors; search & rescue payload ▪ First launch in 2018 LEARN MORE ABOUT GPS III AT AF.MIL

GPS. Control Segment

The Operational Control Segment (OCS) is a global network of ground facilities. It tracks, monitor, performs and sends commands to the GPS constellation.



GPS. User Segment

Receiver Components:

Antenna

Receiver

Display

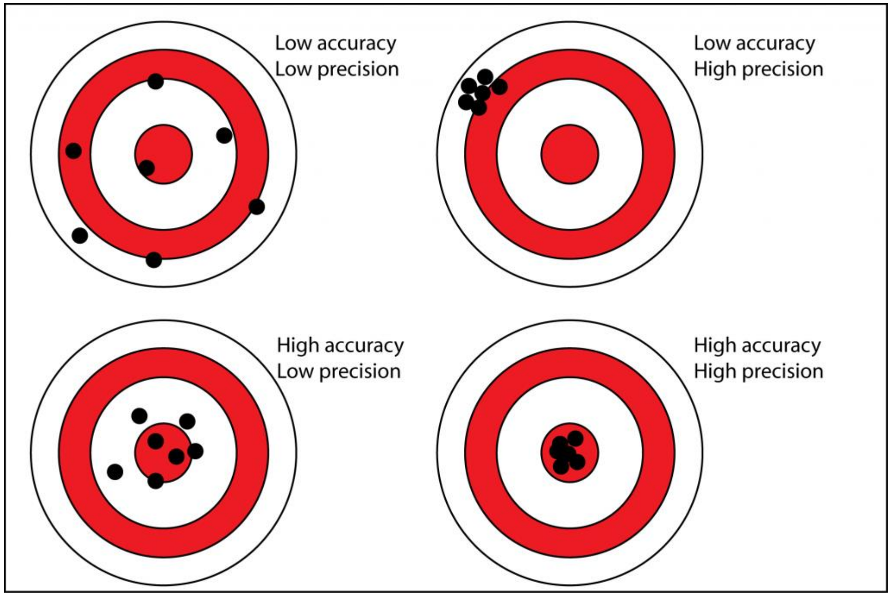
Firmware

Input

GPS. Performance

ACCURACY

«The difference between a receiver's measured and real position, speed or time»

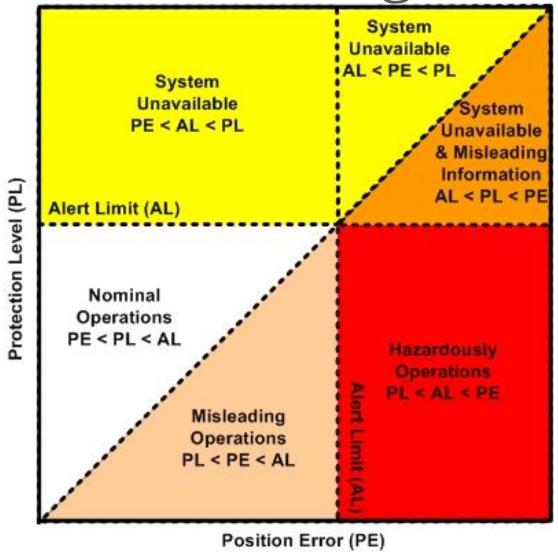


GPS. Performance

INTEGRITY

«System's capacity to provide a threshold of confidence and, in the event of an anomaly in the positioning data, an alarm»

Stanford diagram



GPS. Performance

CONTINUITY

«System's ability to function without interruption»

«The percentage of time a signal fulfils the three accuracy, integrity and continuity criteria»

GPS. Errors Sources

- **Satellite clock**
- **Atmospheric:**

Tropospheric: temperature, pressure, and humidity- 1 m

Ionosphere : layer of ionized air - 10 meters.

- **Receiver clock:** GPS receiver clock can result in 1 m error
- **Satellite orbit**: error in position of a GPS Satellite- 1 m
- **Multipath**: Reflected GPS signals - 0.5 - 2000 meters.

GPS stated accuracy = at least 30 meters 95% of the time

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GPS, Real time applications in Agriculture

GPS technology has advanced impressively in the recent past and has various applications across agriculture:

Soil sampling: GPS helps in distinguishing between soils that are viable and establish which type of soil is ideal for a particular crop.

Weed location: GPS can be used to single out weed patches in vast areas of lands.

Accurate planting: GPS also helps in planning the planting, it is easier to determine spacing between seeds and the depth required.

Soil property mapping: GPS plays an important role in determining the soil property to establish its variability and suitability and consequentlly the type of crop appropiate to be planted on that farm.

GPS, Real time applications in Agriculture

Creation of yield maps: GPS can be used create yield crop maps based on the land characteristics and the seed characteristics.

Harvesting: GPS is helpful to determine what areas are ready to be harvested and how the harvesting will take place. The GPS will also give an estimate of the size of the area being harvested and the expected returns from the area.

Environmental control: GPS can determine the capacity of each square meter to absorb all the pesticide hence it can be reduced the chances of runoff.

GPS, Real time applications in Agriculture

Field mapping: Through the GPS, experts can tell what part of the field will be used for farming activities and what area will be used for other non-farming related activities.

Crop scouting: GPS helps to tell the nature and type of crops that thrive within a given locality and help in improving the quality of that crop.

Assessment for the availability of water in an area: Water sources such as rivers or canals can easily be singled out using GPS.

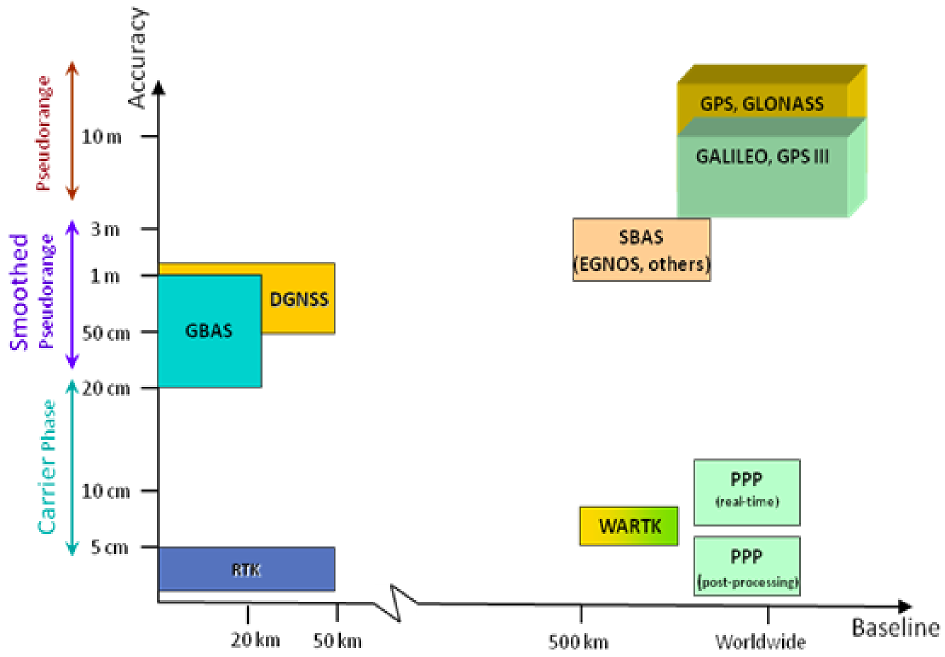
Meteorological mapping such as climatic patterns: GPS plays an important role in mapping out some climatic conditions.

Layout

- **Augmentation Systems**
  - Introduction
  - GBAS
  - SBAS
  - Overview

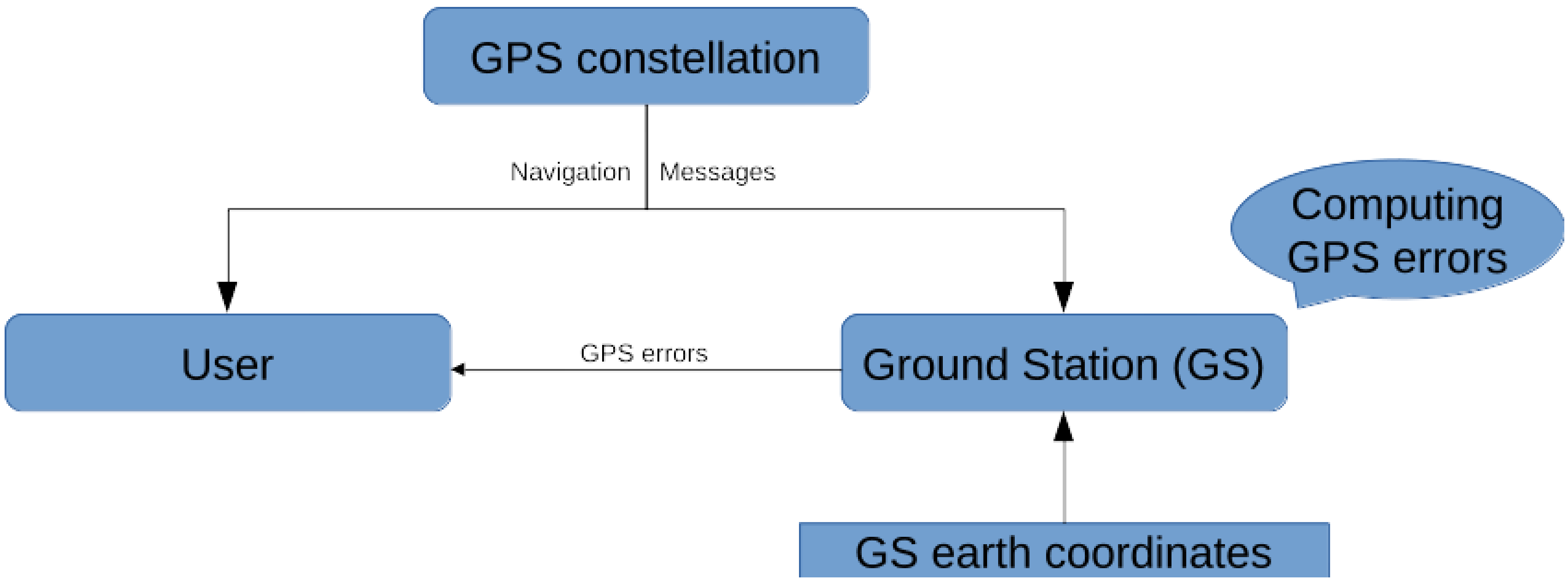
Augmentation systems (AS)

AS is a method of improving the navigation system's attributes, such as accuracy, reliability, and availability and decrease the errors. To choose the most suitable depends on each case, for example on accuracy required:



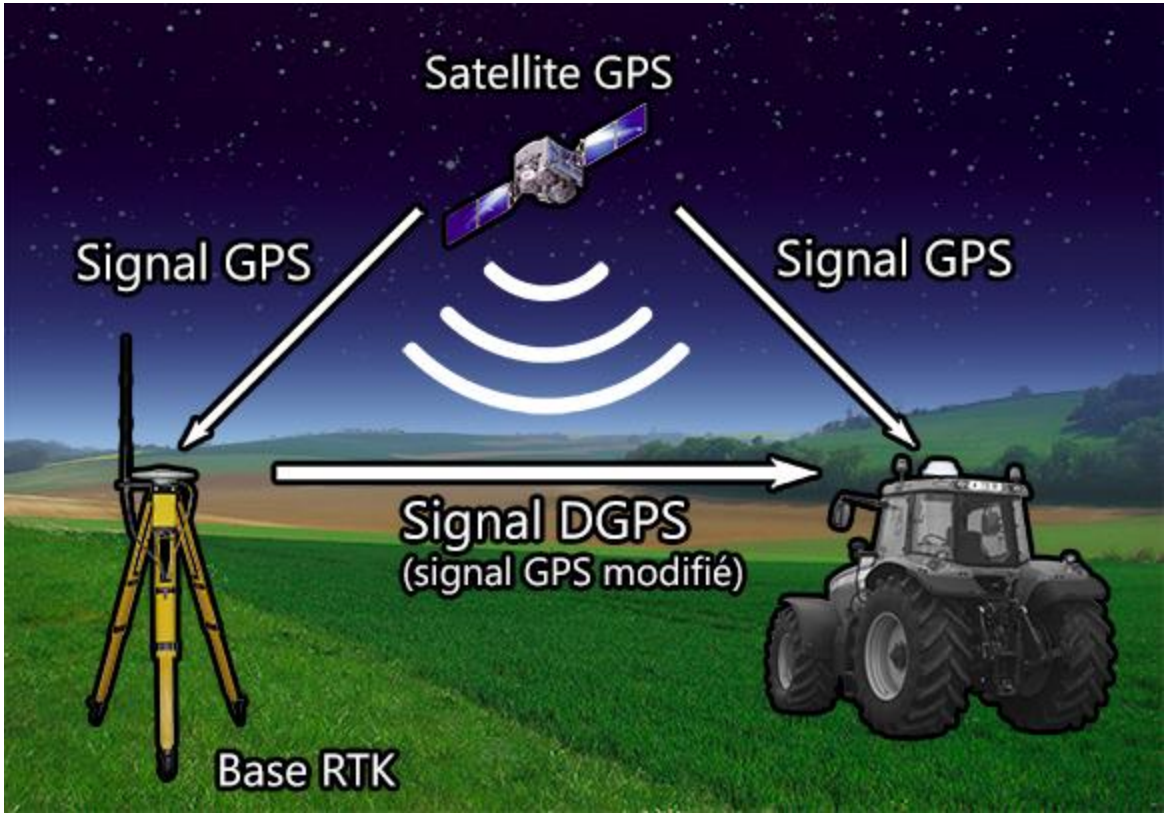
AS. GBAS Definition

Ground Based Augmentation System provides GPS corrections via terrestrial receivers transmitting in VHF or UHF (Ultra and Very High Frecuency).

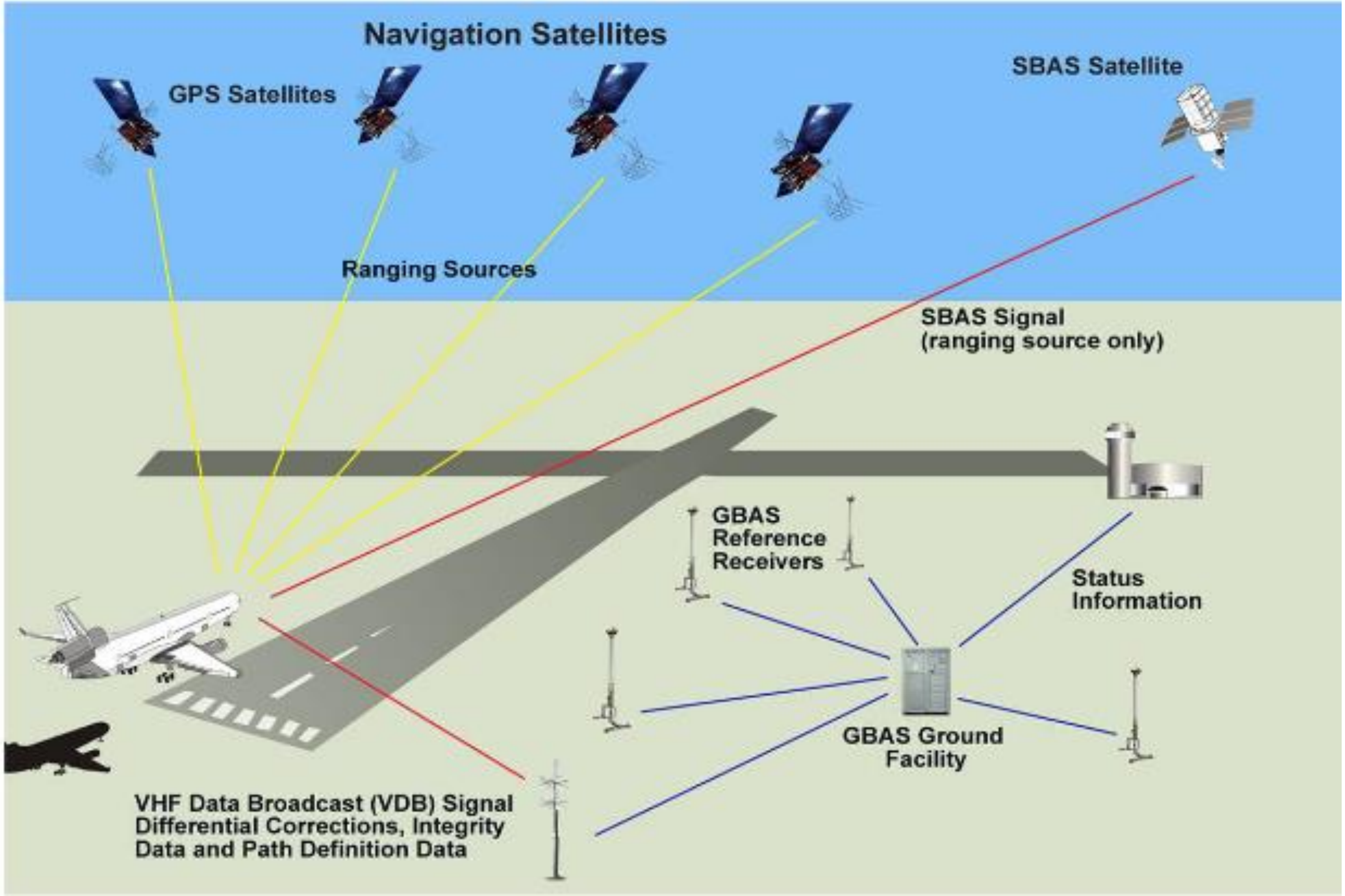


AS. GBAS Examples

- Beacon DGPS
- Comercial DGPS
- RTK / Network RTK
- Widelane RTK



AS. GBAS Examples



AS. SBAS Definition

Satellite Based Augmentation System:

Abosolute positioning within sapce-based reference frame
Wide-area or regional augmentation

Use of geostationary (GEO) satellites which broadcast the augmentation information.

Main goal of SBAS is to provide integrity assurance

Signal-in-space (SIS) from ground infrastructure

AS. SBAS Examples

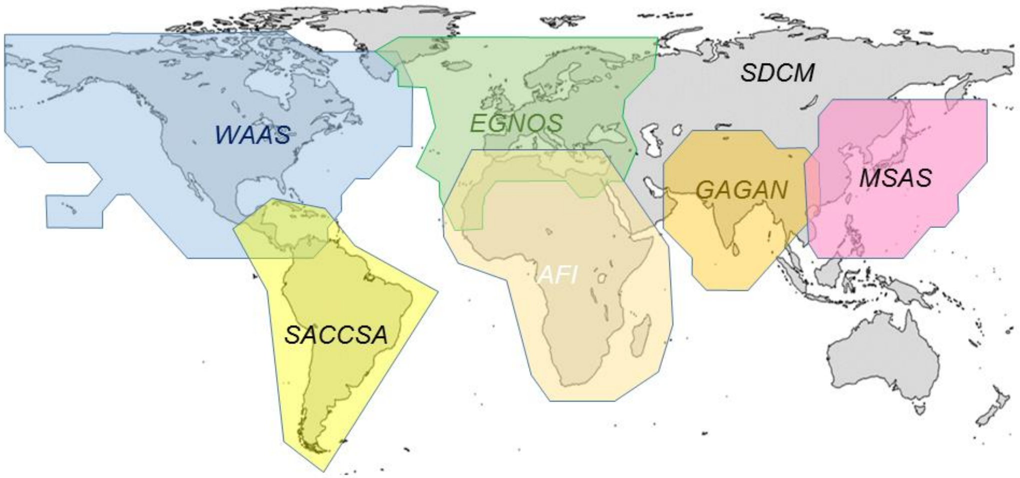
- Most known SBAS systems

Wide Area Augmentation System (WAAS)

European Geostationary Navigation Overlay System (EGNOS)

MTSAT Satellite Augmentation System (MSAS)

StarFire: single set of corrections valid for the entire Earth



Overview AS

System	Horizontal Accuracy	Vertical Accuracy	Typical Range
Total Station	0.01-0.02m	0.01-0.03m	3kms
RTK/Network RTK	0.01-0.05m	0.02-0.10m	10-20kms(Radio link)
SBAS StarFire	0.05-0.10m	0.10-0.20m	Global
Widelane RTK	0.10-0.20m	0.20-0.40m	500-800kms(Satellite link)
SBAS WAAS L1/L2	0.40m	0.60m	USA and Puerto Rico
SBAS EGNOS	0.40m	0.60m	Europe
Commercial DGPS	2m	5m	2000kms
SBAS WAAS L1	3m	7m	USA and Puerto Rico
Beacon DGPS	5m	10m	100-150kms

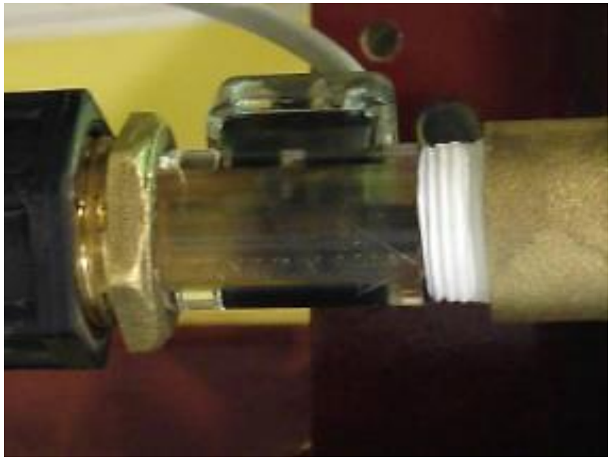
Layout

Remote sensing

- Sensors
- Sensors classification
- Working principle
  - Spectral Bandwidth
  - Resolution
  - Device examples
  - Image examples
- Overview

Sensors

A sensor is a device that responds to a physical stimulus (such as heat, light, sound, pressure, magnetism or particular motion) and transmits a resulting impulse (as for measurement or operating a control).



Flow meter sensor

Ultrasonic sensor

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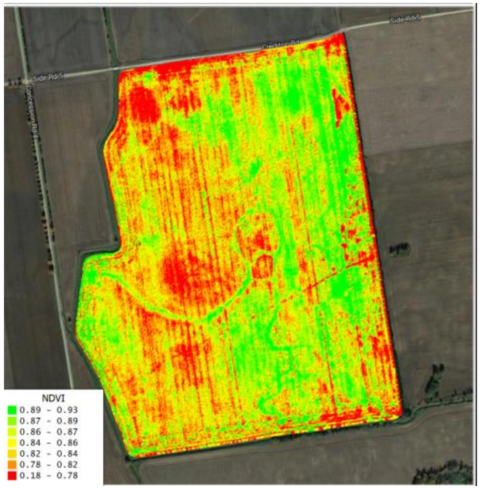
Sensors

Remote sensing

- Photographic camera
- Multispectral sensors



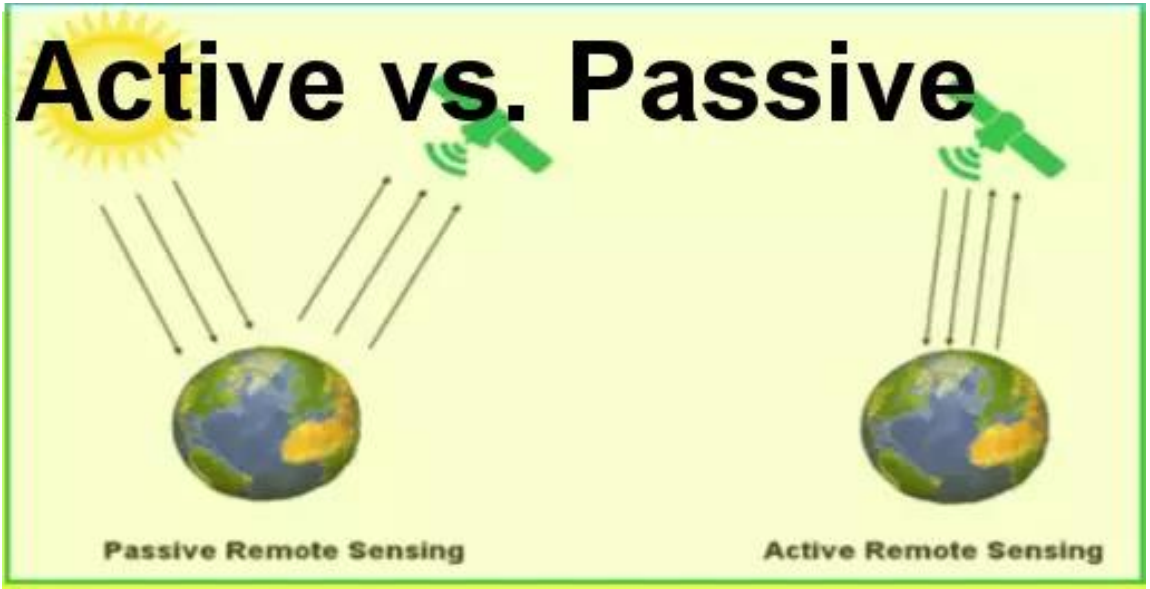
Embedded

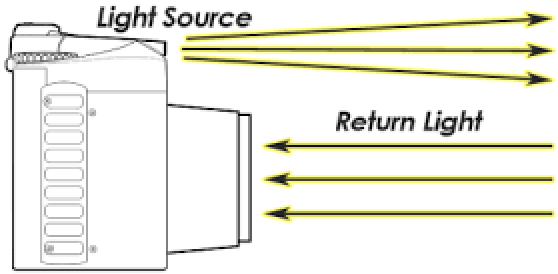
- Ultrasonic sensors
- Radiometry
- Machine vision
- LiDAR

Sensors classification

Passive, Natural electromagnetic radiation (eg. Cameras)

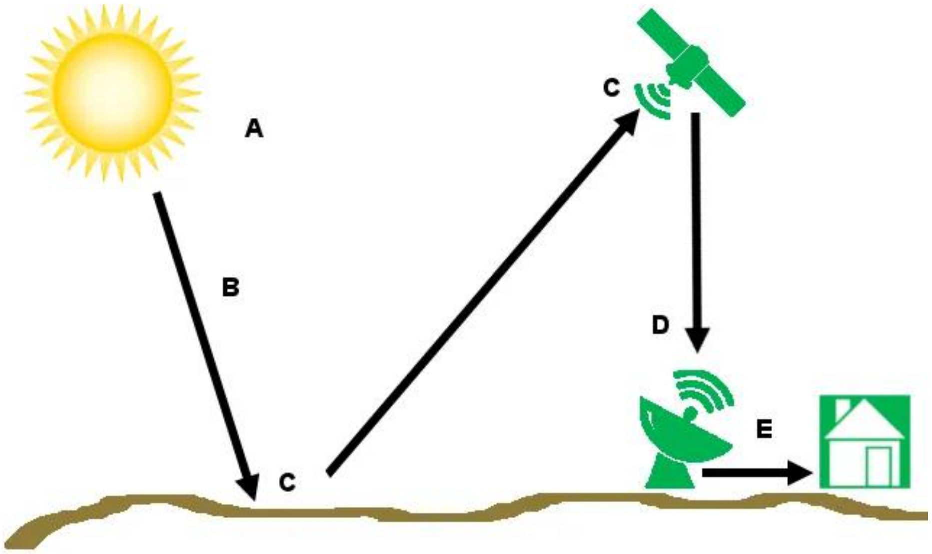
Active, Aartificial electromagnetic radiation (eg. Laser Sensor, cameras with flash)





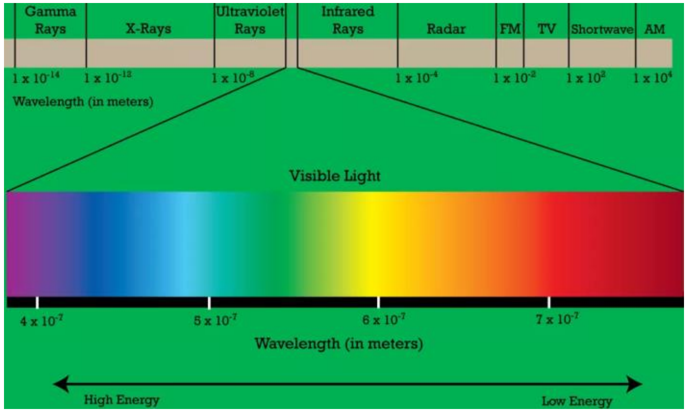
Working principle

«Art and science of acquiring information about the earth surface without having any physical contact with it»

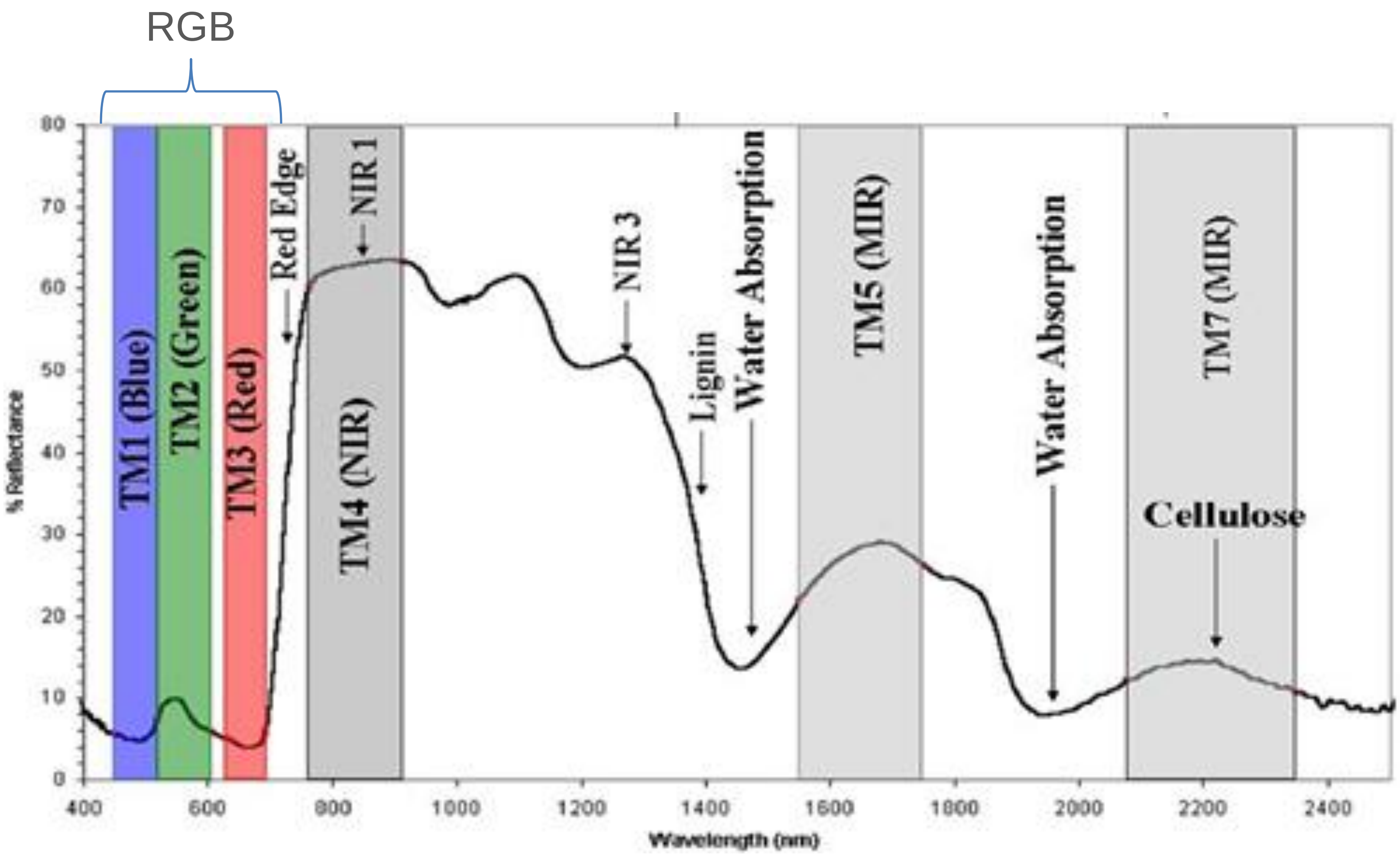


Working principle

a) Energy Sources:
b) Electromagnetic radiation to the Target interest (eg: Sun)
c) Atmosphere and Radiation:
d) Path from source to earth surface and from earth surface to sensor
e) Interaction with the Target and Recording of the Reflected Energy
f) Energy reflected by target. This Electromagnetic radiation is classified from km to nm, divided by ranges called spectral bands.
g) Transmission and Ground level Processing
h) Transform this energy to electronic signals
i) Interpretation, Analysis and Application
j) Visual interpretation and originality on the applications!



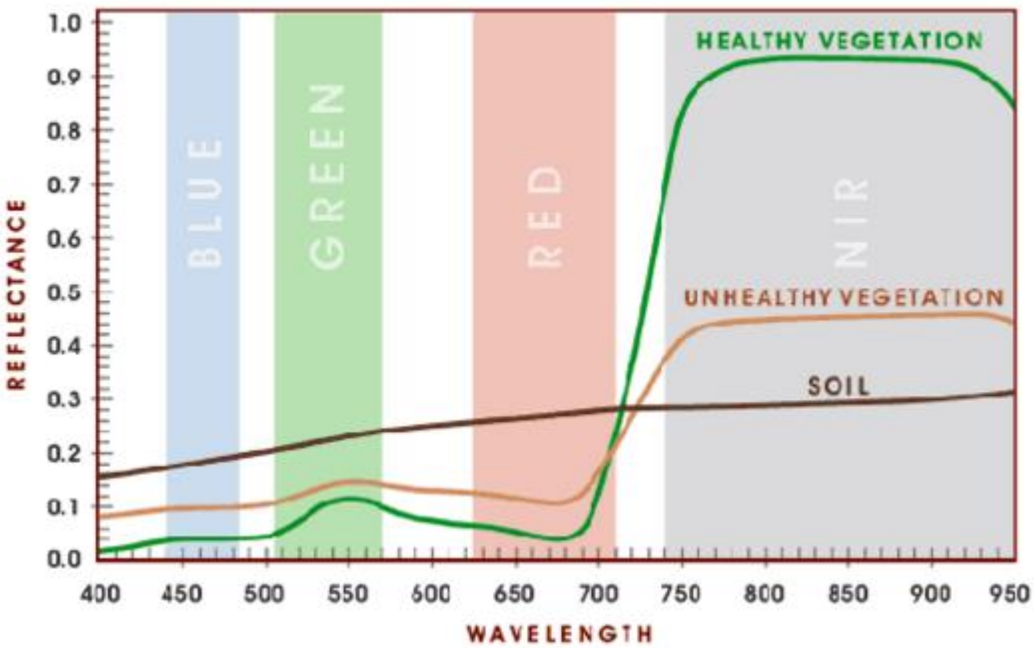
Spectral bandwidth

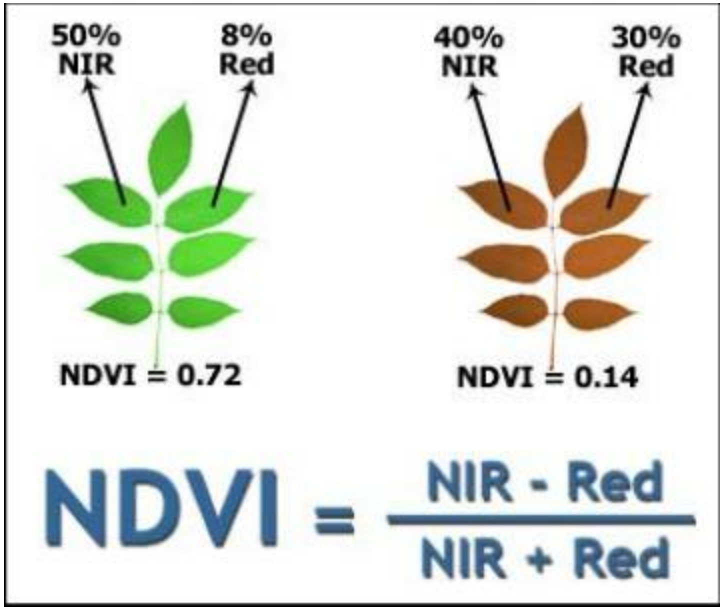


Spectral bandwidth

NDVI (Normalized Difference Vegetation Index) is the most well-known parameter in this field. It is related with plant vigour

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

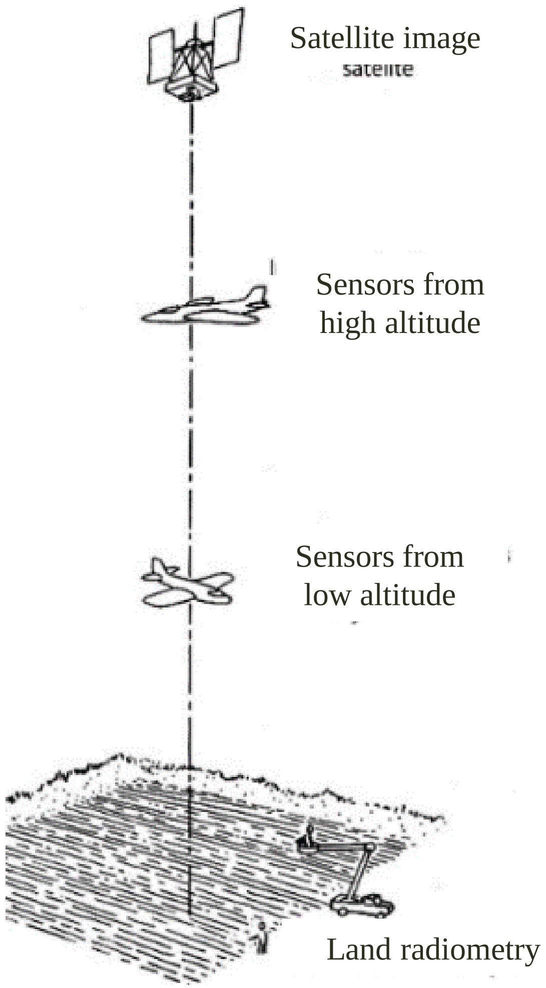




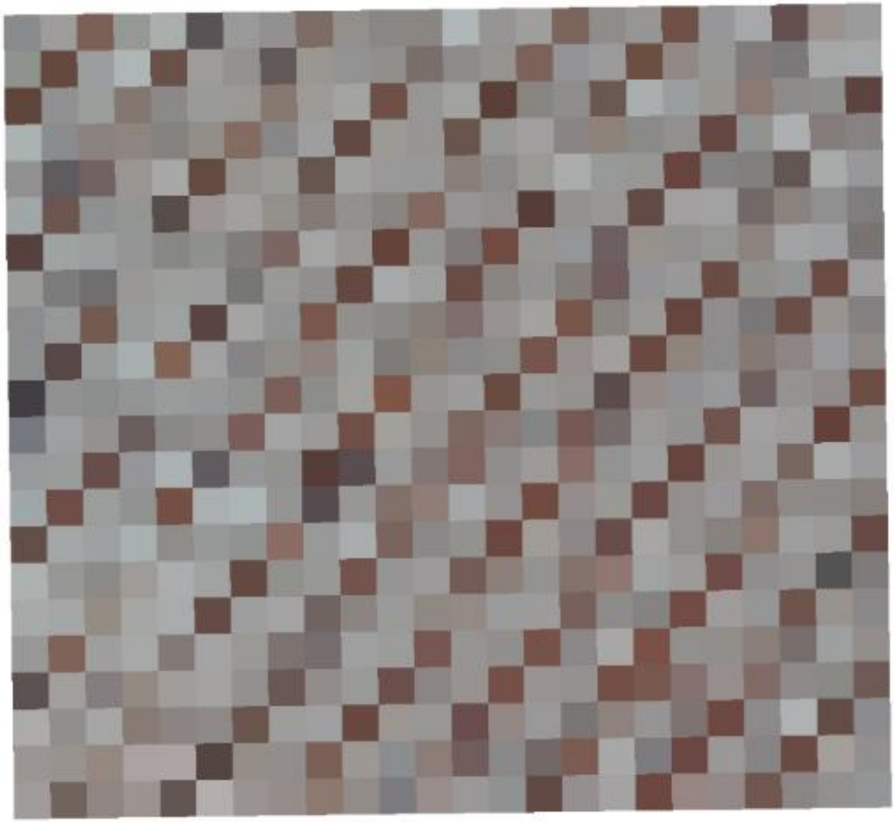
Resolution

Area: 13 ha
Flight time: 15 min
Resolution: 2 cm/pixel – 575 Mb

Resolution



2.6 m/pixel



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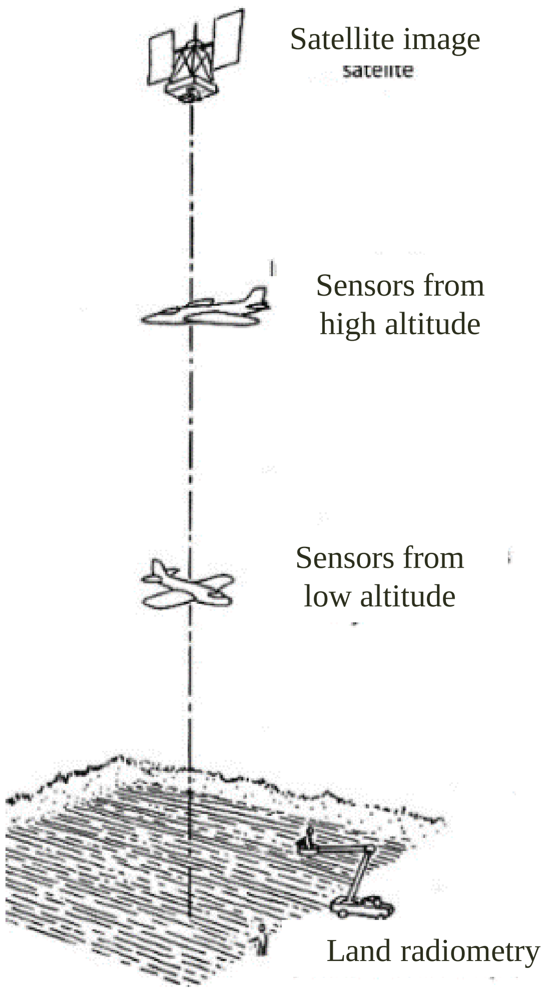
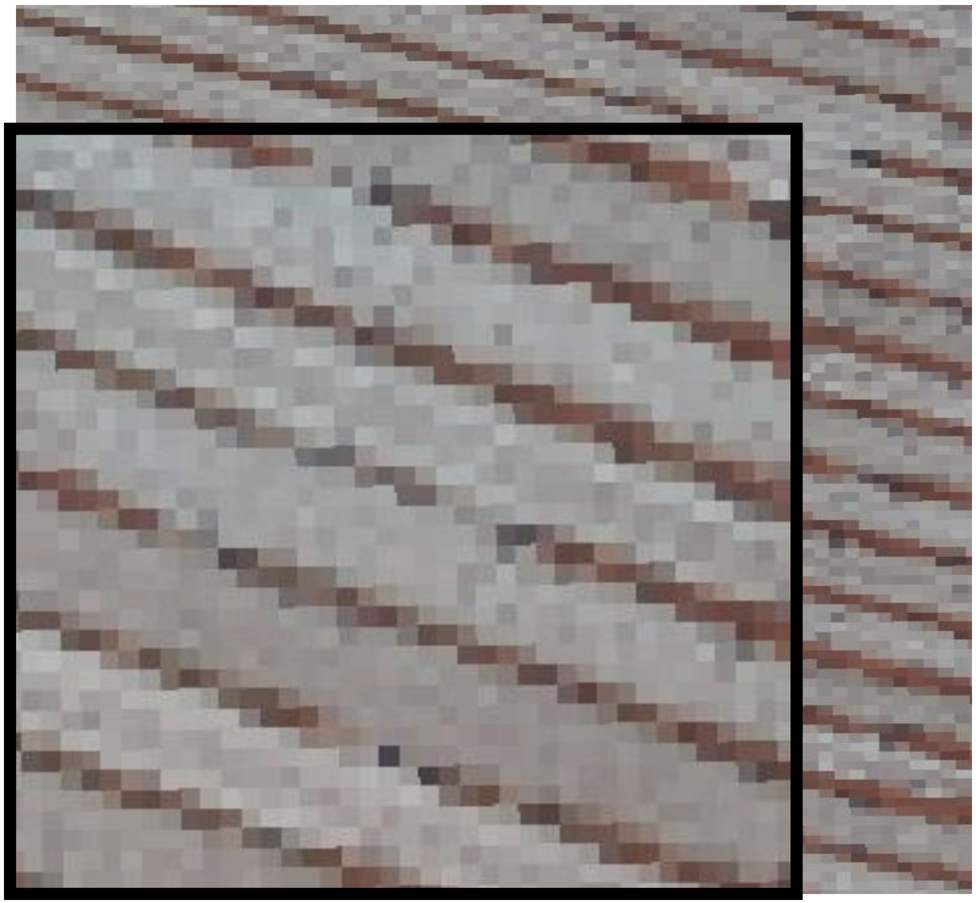
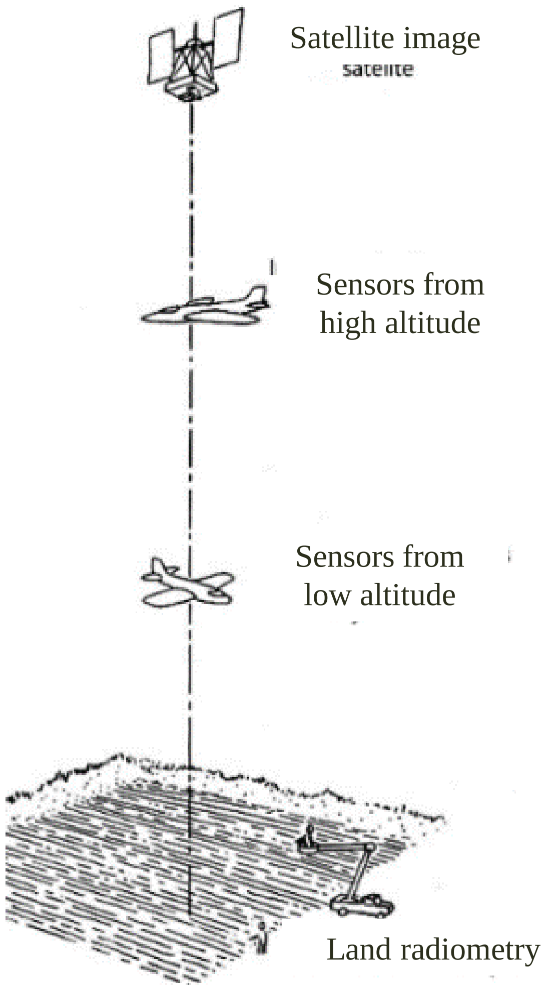
Resolution



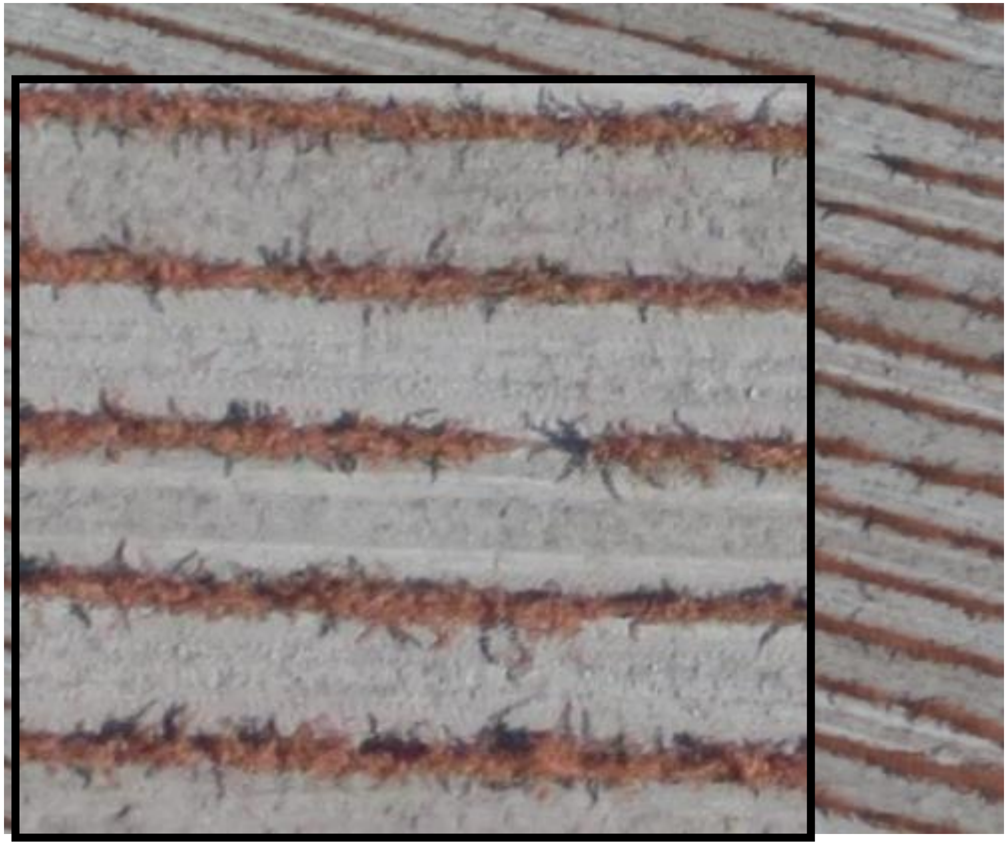
0,5 m/pixel



Resolution



3 cm/pixel



Device examples

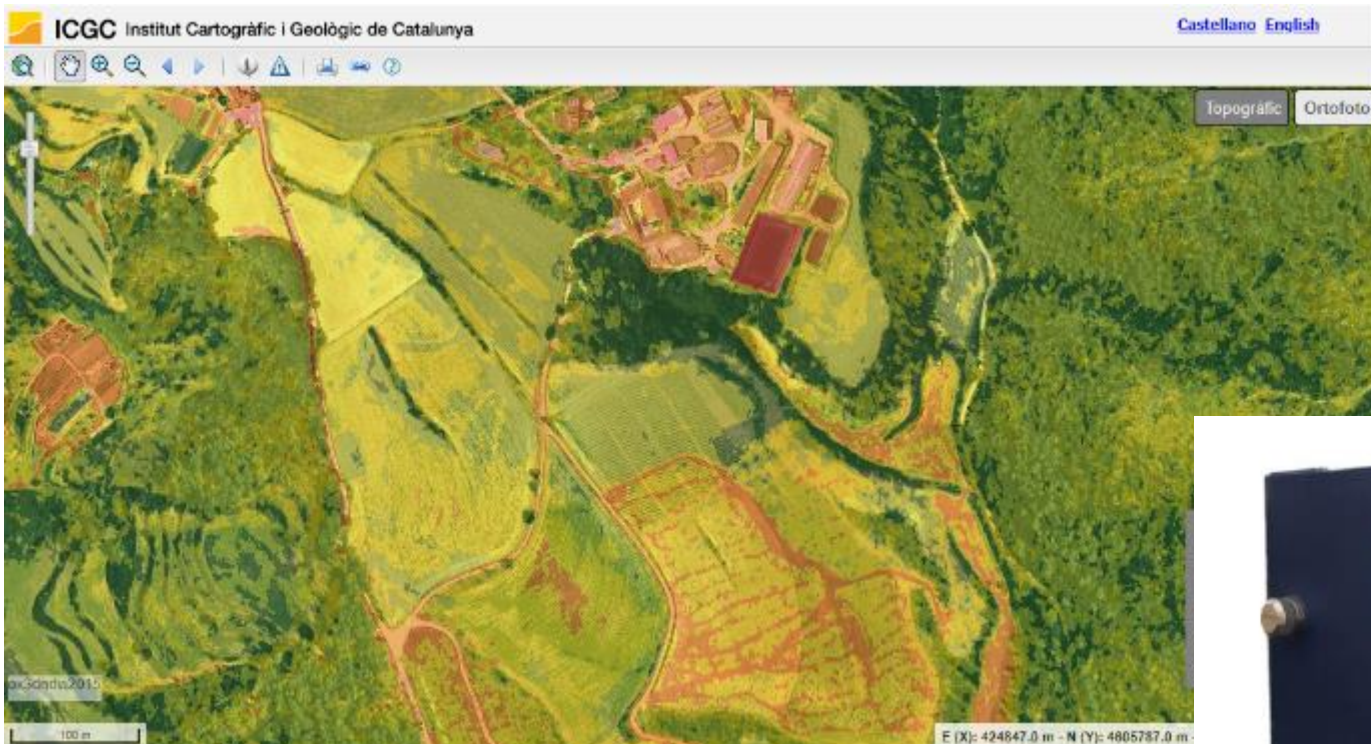
- Photographic camera and multi-spectral sensor

Image Examples

- Data obtained with photographic camera

Image Examples

- NDVI data obtained from a satellite capture



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Layout

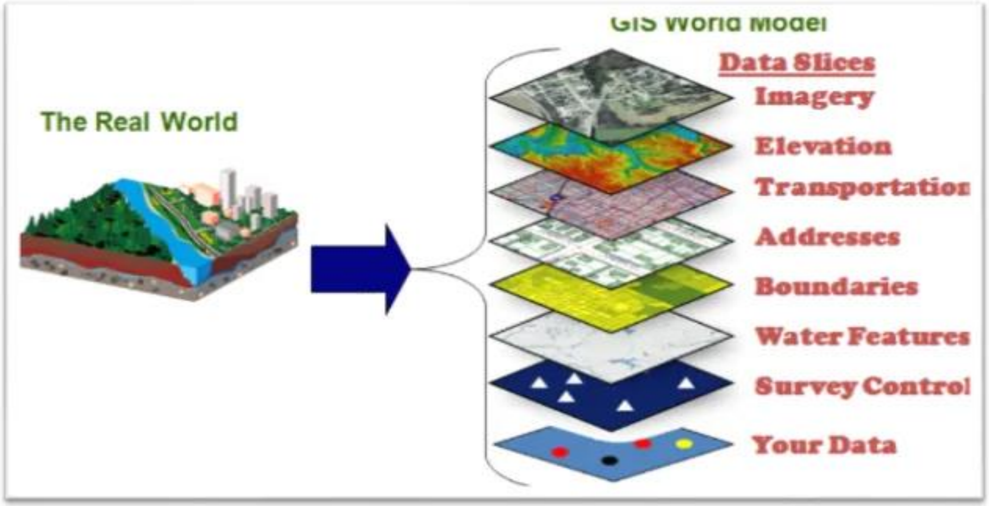
- **Geographic Information System (GIS)**
  - Definition
  - Components
  - Principle
  - Data types

GIS. Definition

«Geographic Information System (GIS) is a computer system capable of assembling, storing, manipulating and displaying geographically referenced information»

«A GIS is an organized collection of computer hardware, software, geographic data and personnel to efficiently capture, store update, manipulate, analyze and display all forms of geographically referenced information»

https://grindgis.com/what-is-gis/what-is-gis-definition



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GIS. Components

Hardware is the computer on which GIS software runs.

Software provides tools to run and edit spatial information, it helps to query, edit, run and display GIS data. Eg: ArcGis, QGIS...

Data is the most important element and heart of GIS. It is a combination of graphic and tabular data. Graphic can be vector or raster.

People are user of Geographic Information System. They run the GIS software. includes both GIS professionals and end users.

Methods are the functions which provides data analyzing, manipulating and handling capabilities to the GIS.

GIS. Principle

Data capture: The original data is obtained from digitalitzation and scanning of a aerial photographs, paper maps among others

Database Management and analysis: Security, integrity, storage, interpretation qualitatively and quantitavety

Results: the most useful tools on GIS are the multiple ways to present the data.

GIS. Data models

1) Raster Data model

1) Vector data model

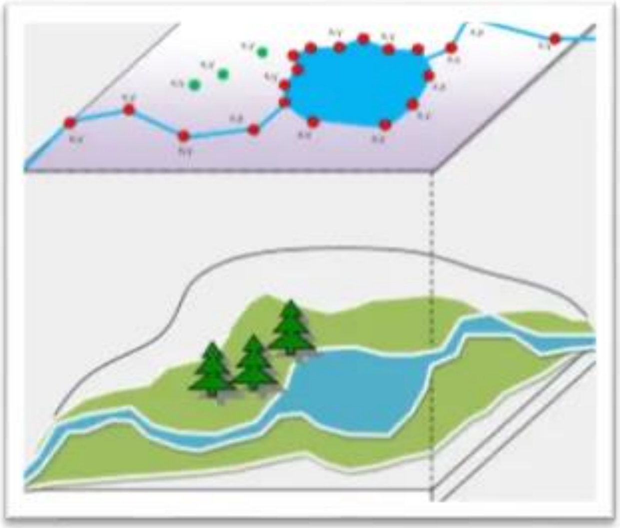
1) Triangulated irregular network model (TIN)

1) Digital elevation model (DEM)

1) Network models

GIS. Vector Data

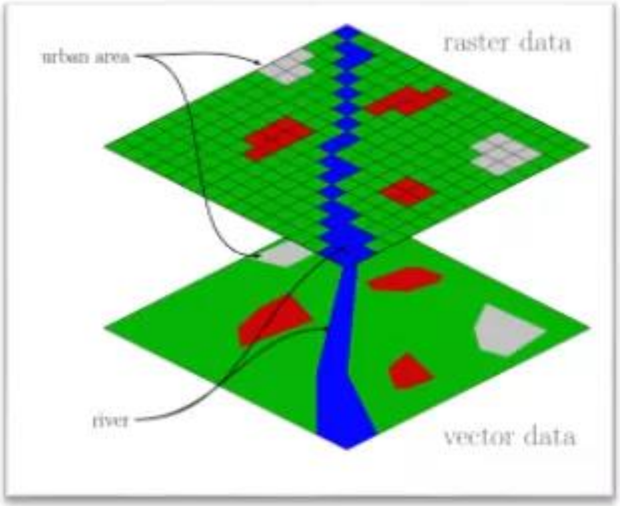
Vector Data: models data to points, lines or polygons.



But nature features such temperature, rainfall, humidity... are not best described in a vector data model.

GIS. Raster Data

Raster Data: store information of features in cell based manner. Each pixel could contain different attributes.



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Advantages of GIS

- GIS allows us to view, understand and visualize data in many ways reaveling relationships, patterns and trends in the form of maps, globes, reports and charts.
- The multiple results forms gives you the possiblity to present your data in the best comprensive way.
- GIS have a great accuracy in predictions and analysis

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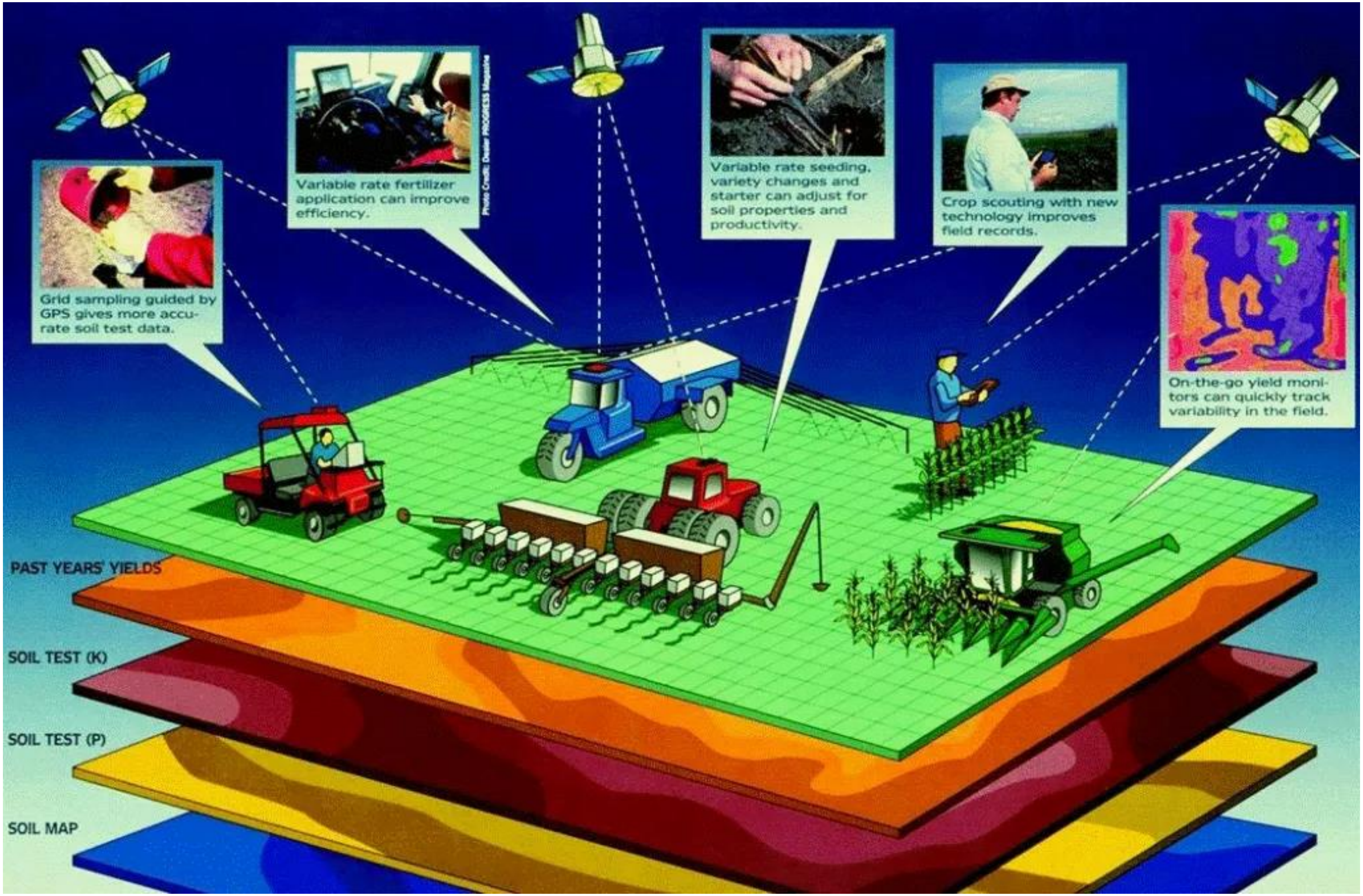
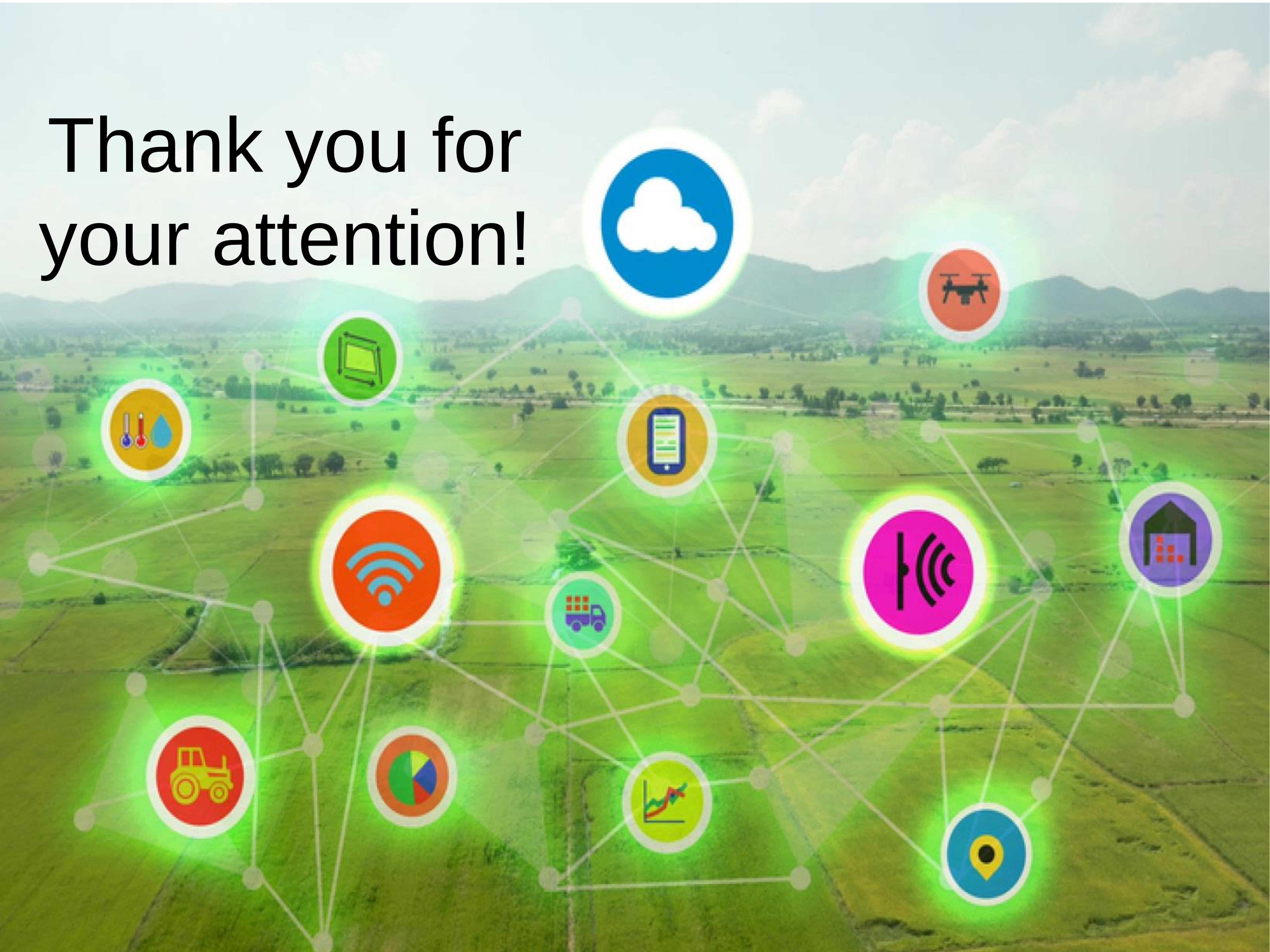
Disadvantages of GIS

- Excessive damage in case of internal fault. Long outage periods as repair of damage part at site.
- Expensive software.
- Integration with traditional map is difficult.


Variable rate fertilizer application can improve efficiency.
Variable rate seeding, variety changes and starter can adjust for soil properties and productivity.
Crop scouting with new technology improves field records.
Grid sampling guided by GPS gives more accurate soil test data.
On-the-go yield monitors can quickly track variability in the field.
PAST YEARS' YIELDS
SOIL TEST (K)
SOIL TEST (P)
SOIL MAP

Thank you for your attention!



AgrICT

Development of a Training Program for Enhancing the Use of ICT Tools in the Implementation of Precision Agriculture

Project coordinator

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Partners

INRAE

AARHUS UNIVERSITET

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AGRICULTURAL UNIVERSITY OF ATHENS
ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

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