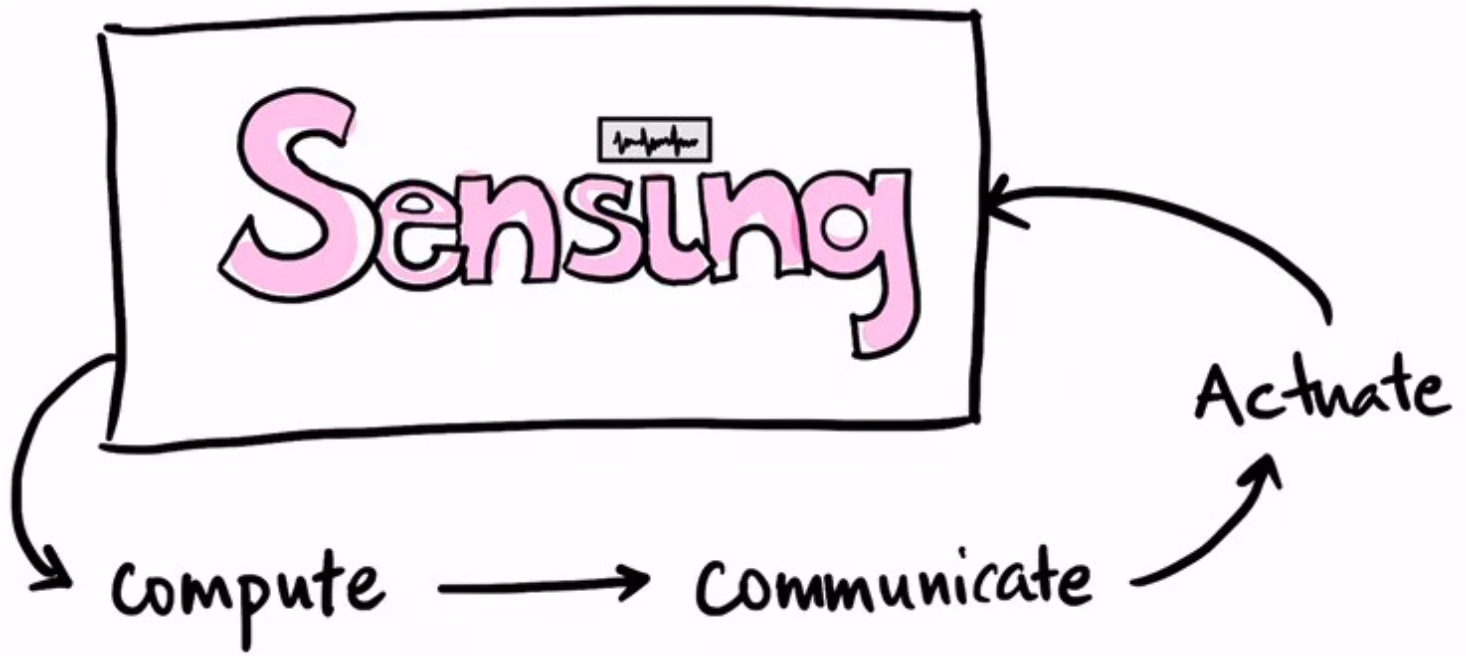
University of Illinois at Urbana-Champaign
Dept. of Electrical and Computer Engineering

ECE 101: Computing Technologies and the Internet of Things

Sensing
(part 2 of 2)

Sense-Compute-Communicate-Actuate Loop

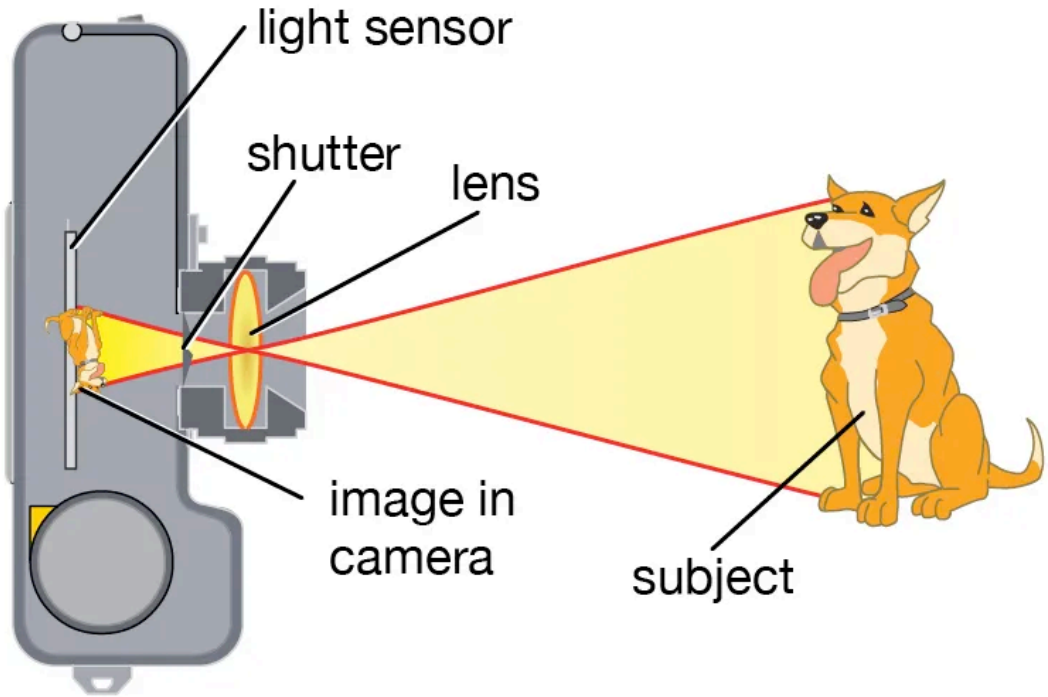


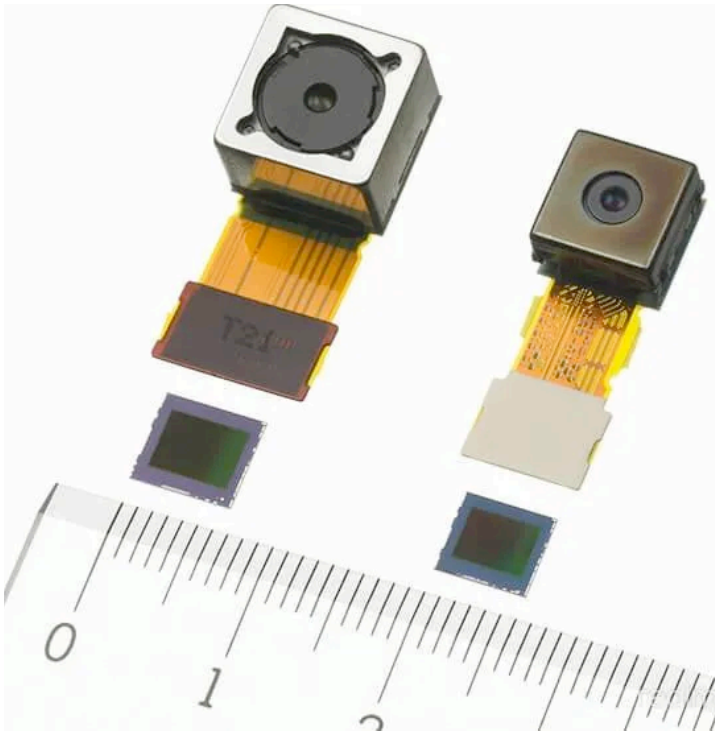
A Brief List of Sensors in Use Today

Types of sensors

1. **Cameras**: IR, thermal, radar, LIDAR
2. **Microphones**: audible, ultrasound
3. **IMU**: **I**nertial **M**easurement **U**nit (accelerometer, gyroscope, magnetometer)
4. **Wireless**: GPS, Wifi (WiGig 60GHz, THz), UWB
5. **Assorted**: pressure, humidity, proximity, temperature, chemical traces

The Humble Camera



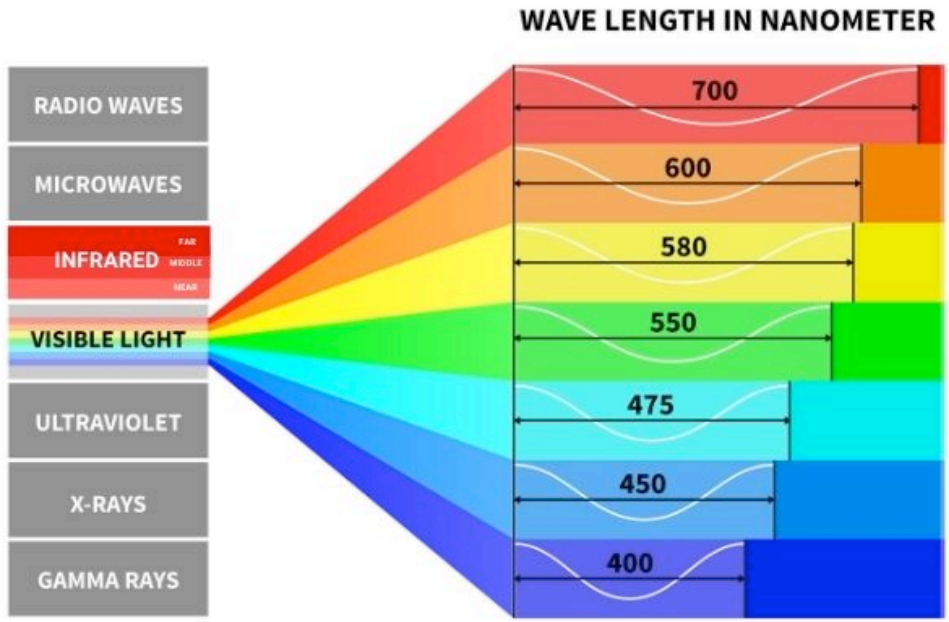


https://kids.britannica.com/kids/article/camera/399387

https://c.realme.com/in/post-details/1388189721108160512

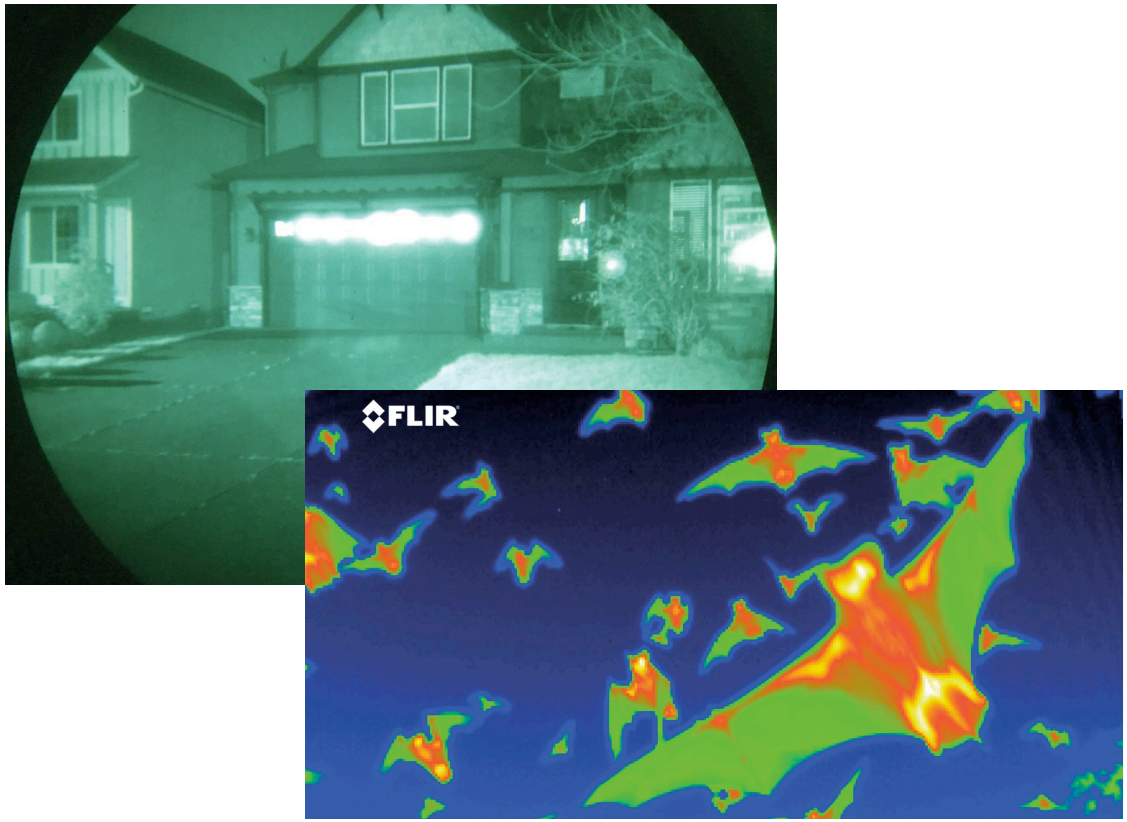
Infrared and Thermal Imaging

- **Infrared Radiation**: A type of electromagnetic radiation with wavelengths longer than visible light but shorter than microwaves.
- **Thermal Imaging**: A technique that detects infrared radiation (heat) emitted by objects and converts it into an image.



Difference Between Infrared and Thermal Imaging

- **Infrared Imaging**: Captures infrared light **reflected off objects**, often used in night vision devices.
- **Thermal Imaging**: Captures infrared **radiation emitted by objects**, used to visualize temperature differences.

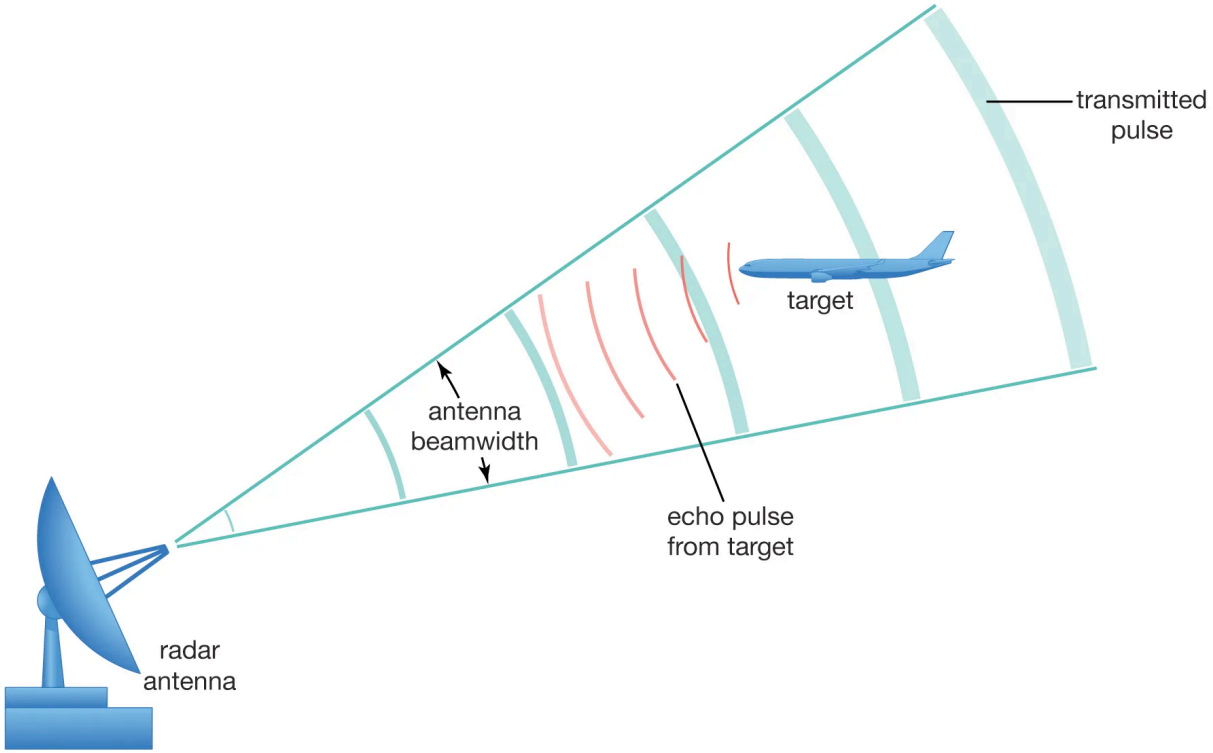


Applications of Infrared and Thermal Imaging

1. Home Security
   - **Night Vision Cameras**: Use infrared imaging to capture clear images in low-light conditions, enhancing home security.
   - **Example**: Many home security systems use infrared cameras to monitor properties at night.
2. Medical Diagnostics
   - **Detecting Fevers and Inflammation**: Thermal imaging can identify areas of the body with elevated temperatures, useful for diagnosing fevers and inflammation.
   - **Example**: Thermal cameras are used in airports to screen passengers for fevers during health outbreaks.
3. Industrial Uses
   - **Equipment Maintenance**: Thermal imaging helps detect overheating components and potential failures in machinery, preventing costly breakdowns.
   - **Example**: Industrial plants use thermal cameras to monitor equipment and ensure safe operation.

Bats and Echolocation

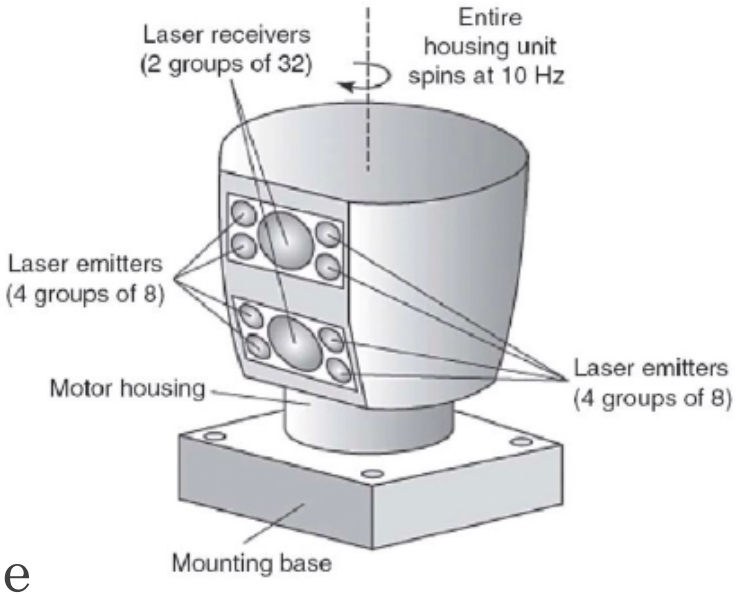
RADAR: RAdio Detection and Ranging



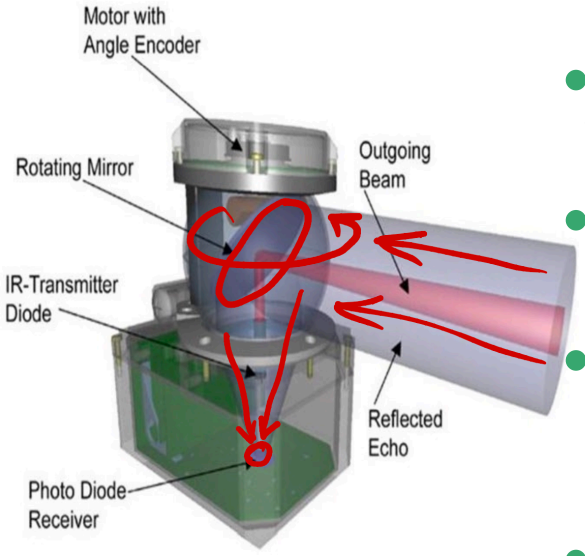
Ref: https://www.britannica.com/technology/radar

LIDAR (LIght Detection And Ranging)

- A remote sensing method that uses light in the form of a pulsed laser to measure variable distances from an object.
- Components of a LIDAR System
  - **Laser**: Emits pulses of light.
  - **Scanner**: Directs the laser pulses across the target area.
  - Optional **GPS Receiver**: Provides precise location data for each measurement.



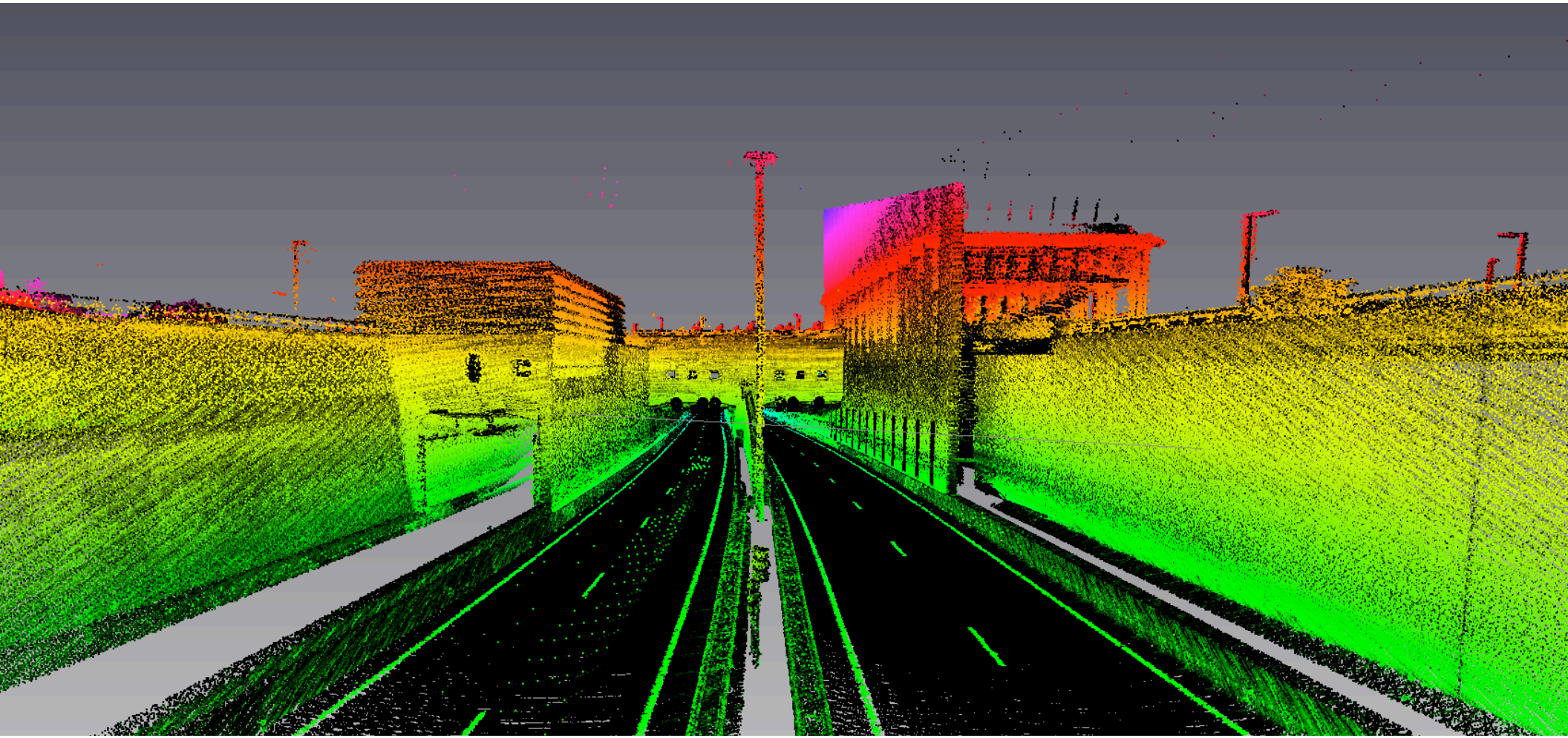
How does LIDAR work?



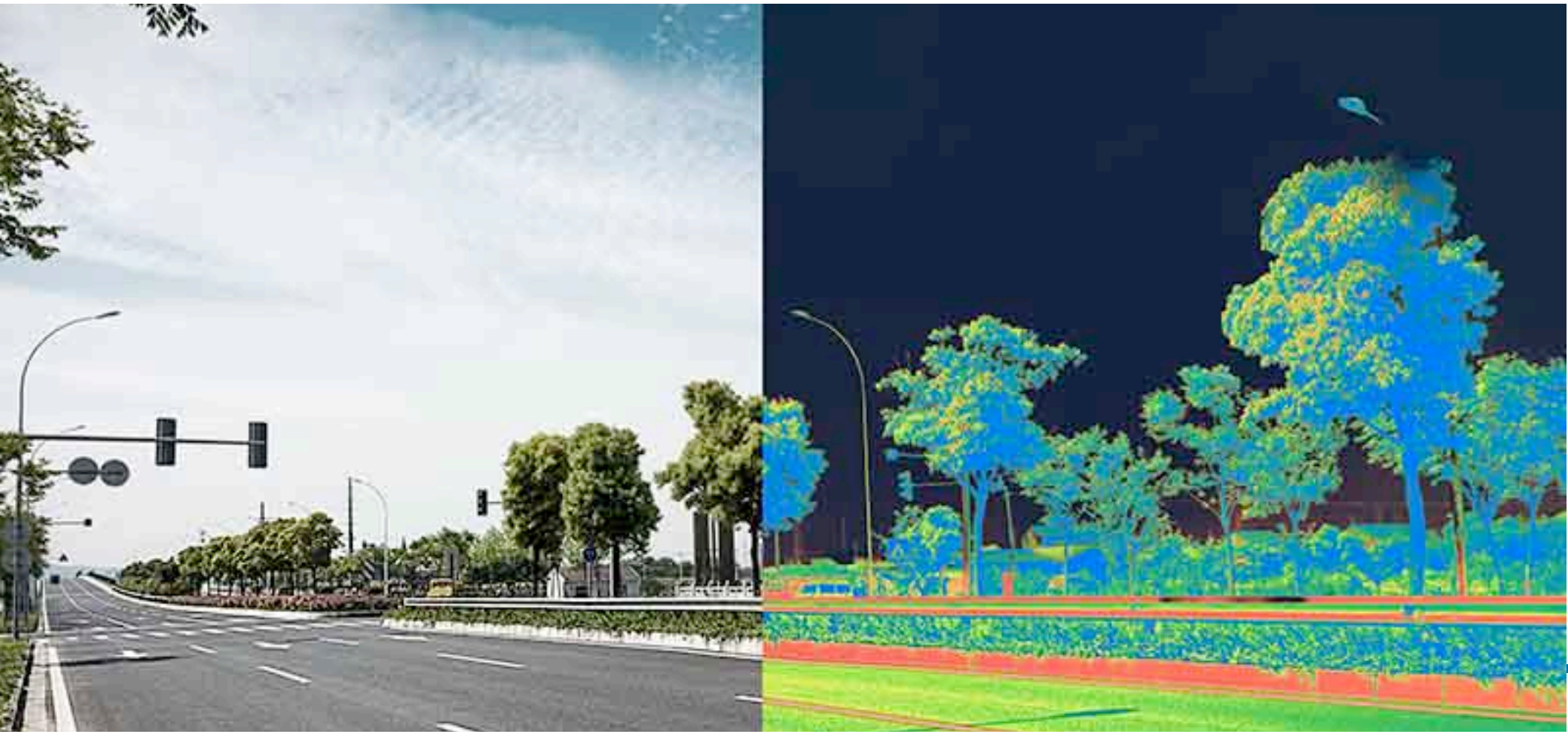
- **Emission** and **Reflection**
  - The laser emits thousands of pulses per second.
  - These pulses travel to the target and reflect back to the sensor.
  - The time it takes for each pulse to return is measured.
  - The return time is used to calculate the distance between the sensor and parts of the target.
  - By combining these distance measurements a detailed 3D map of the target area is created.

3D Point Cloud from LIDAR

3D Point Cloud from LIDAR



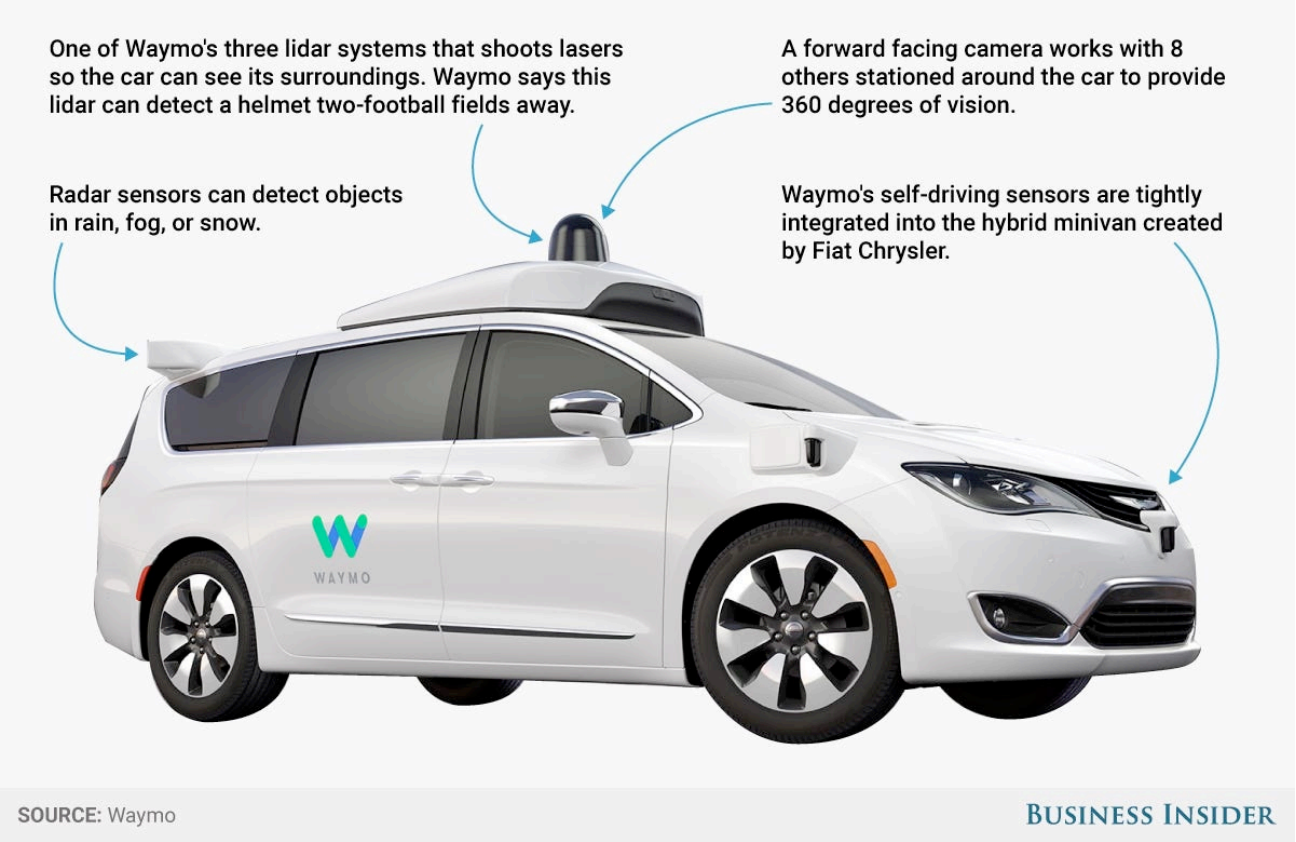
3D Point Cloud from LIDAR



LIDAR applications: Self Driving Cars

Navigation and Obstacle Detection

LIDAR is used in self-driving cars to create **real-time 3D maps of the environment**, helping the vehicle navigate and avoid obstacles.



LIDAR applications: Self Driving Cars

Other Applications of LIDAR

Mapping and Surveying

- **Creating Detailed 3D Maps**: LIDAR is used to produce high-resolution topographic maps, which are essential for urban planning, construction, and land surveying.
- **Example**: LIDAR is used by Google Earth to create detailed 3D representations of cities and landscapes.

Environmental Monitoring

- **Forest Management**: LIDAR helps in measuring forest canopy heights, biomass, and carbon stocks, which are crucial for managing forest resources and studying ecosystems.
- **Example**: The U.S. Forest Service uses LIDAR to monitor forest health and manage wildfire risks.

Other Applications of LIDAR

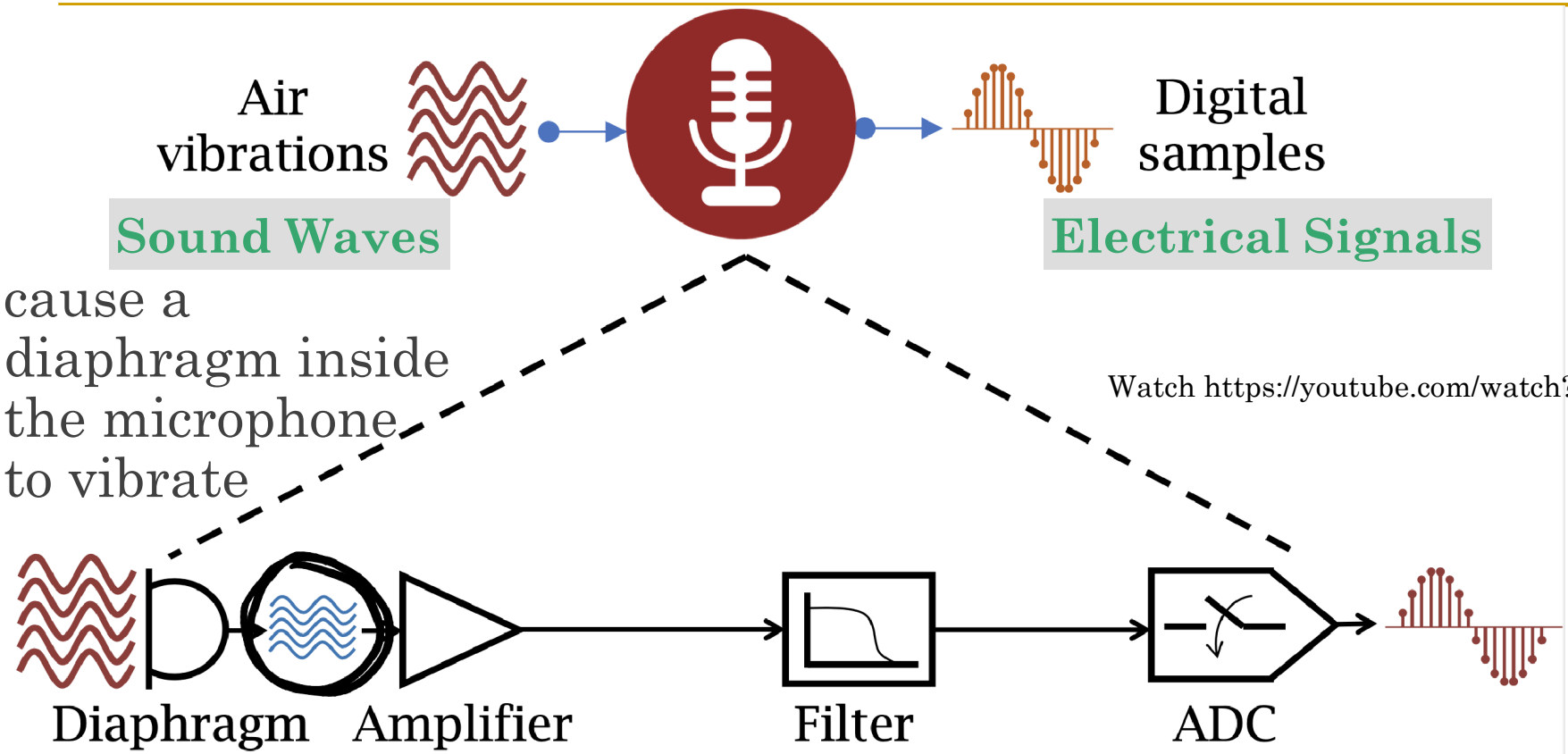
Agriculture

- **Precision Farming**: LIDAR is used to analyze crop health, soil properties, and field topography, enabling farmers to optimize planting, irrigation, and harvesting.
- **Example**: Farmers use LIDAR data to create variable rate application maps for fertilizers and pesticides.

Archaeology

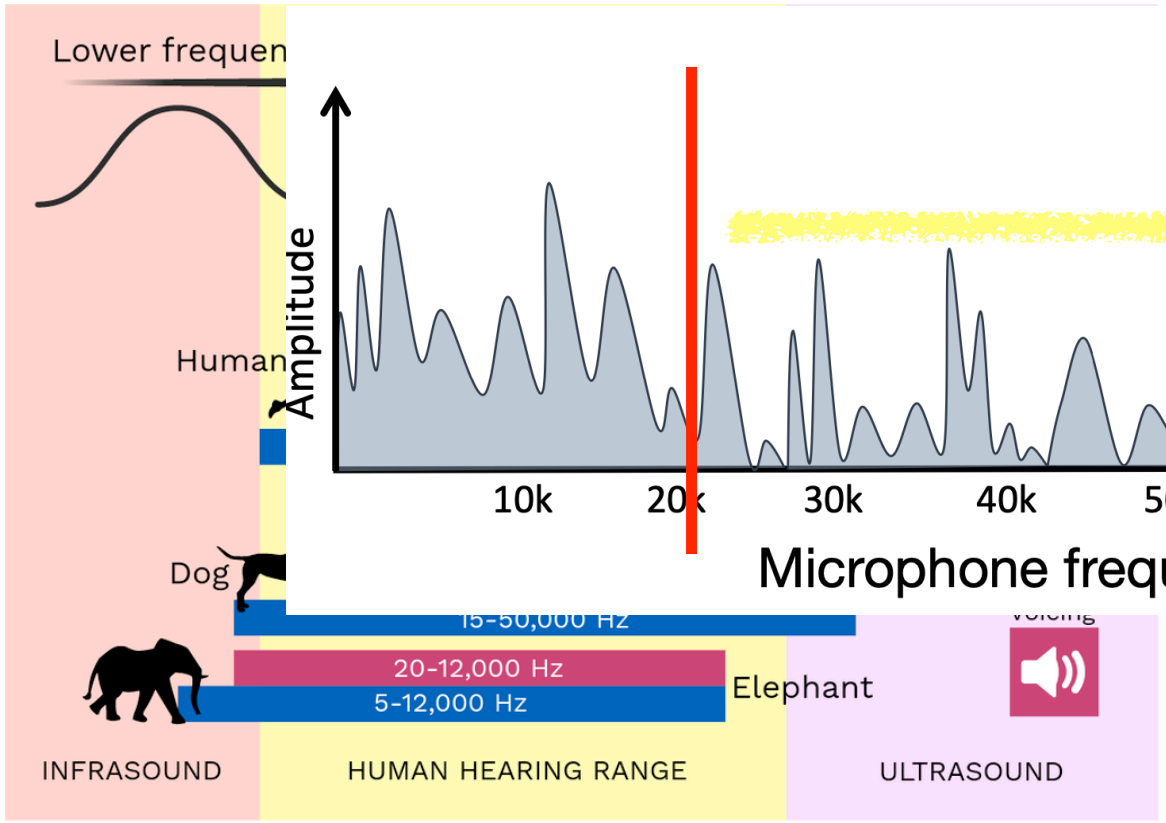
- **Discovering Hidden Structures**: LIDAR can penetrate forest canopies and reveal hidden archaeological sites, such as ancient ruins and settlements.
- **Example**: LIDAR was used to uncover the ancient Mayan city of Caracol in Belize, revealing structures hidden beneath dense jungle foliage.

Microphones



Watch https://youtube.com/watch?v=d_crXXbuEKE

Audio Frequency Range



Possible to generate audio signals that you cannot hear but the microphone picks up!!

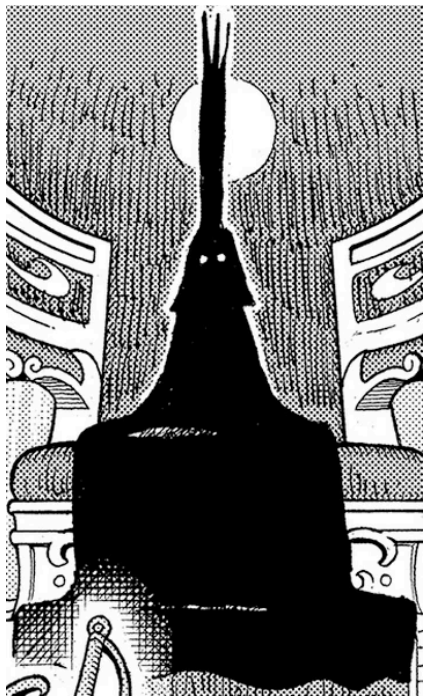
IMU: Inertial Measurement Units

A sensor that tracks the acceleration and angular velocity of an object over a period of time.

If needed it can also track the Earth's magnetic field.

It provides

- real-time motion detection,
- gesture and activity recognition
- helps with optical image stabilization (OIS)
- indoor navigation,

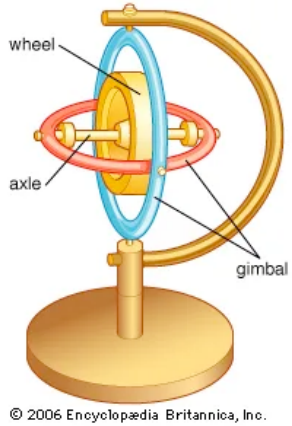


IMU Components

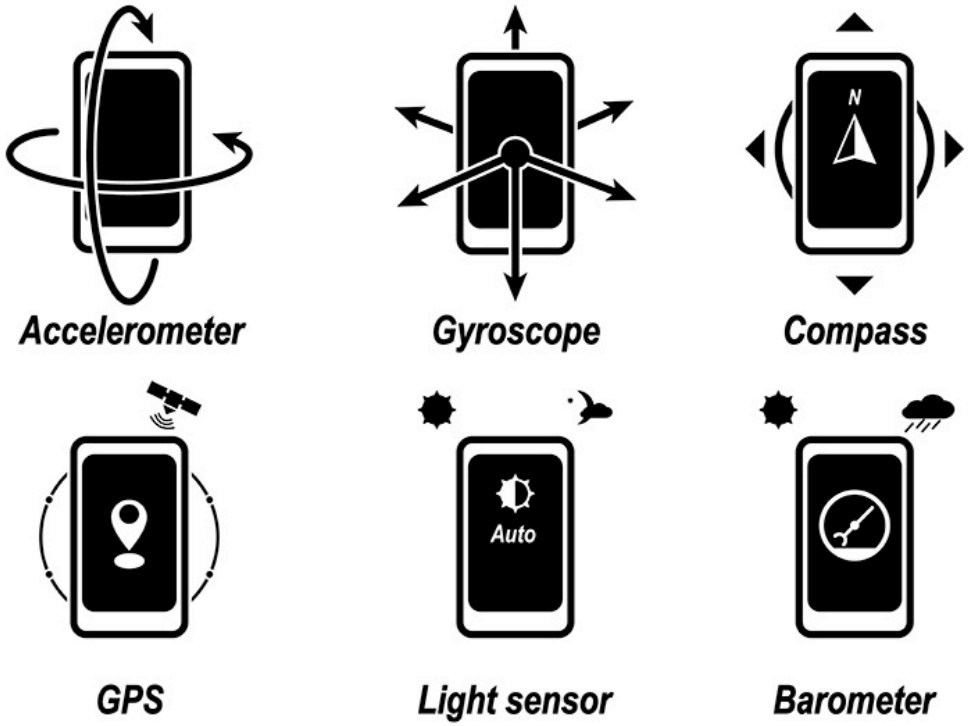
Three types of sensors (usually):

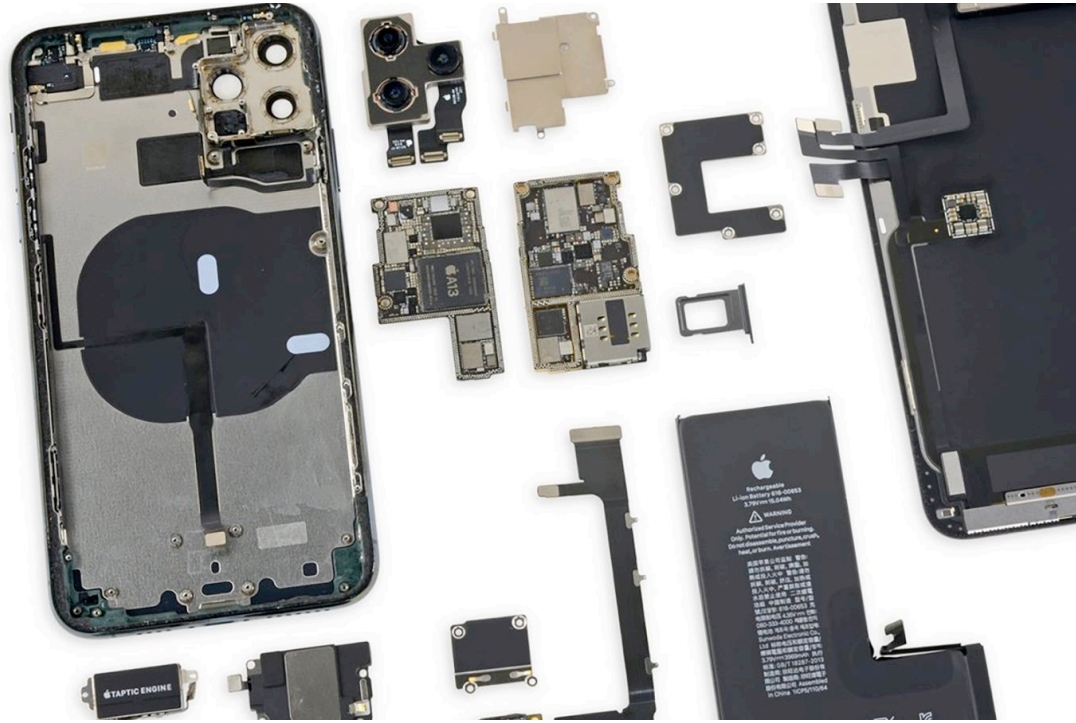
- **Accelerometer**: measures velocity and acceleration
- **Gyroscope**: measures rotation and rotational rate
- **Magnetometer**: establishes cardinal direction (directional heading)

These sensors are a type of **MEMS** (Micro ElectroMechanical Systems)



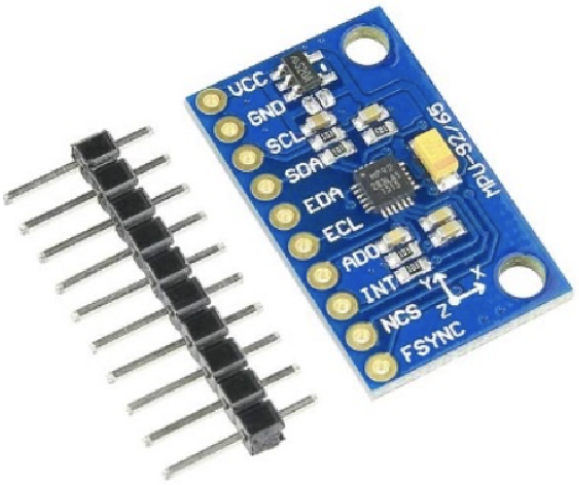
MEMS makes it possible to add IMU and other Sensors in Phones





IMU Applications

- It is used in smartphones and tablets to analyze the user's movements



Accelerometer

Gyroscope

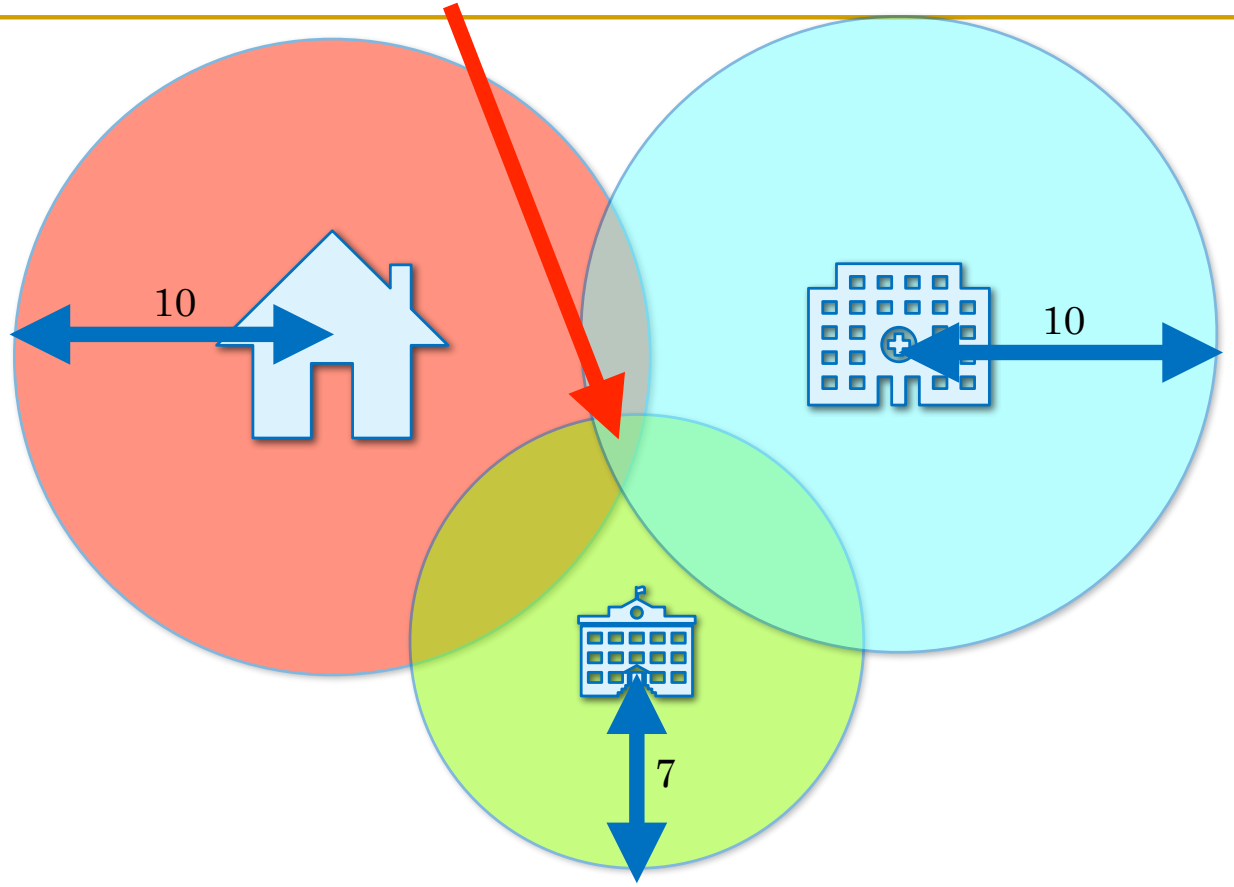
Magnetometer

- Portrait to landscape or current speed in driving app
- 360 photospheres or tilting screen to steer in racing games
- Compass mode in maps or even metal detector apps

IMU Applications

- IMUs are used in headsets to track head orientation and in handheld controllers to capture hand movement
- In fitness trackers and sports equipment, this technology can be used to capture and analyze athletes' movements
- On manned and unmanned aircrafts, an IMU's measurements can be used to calculate altitude and relative position

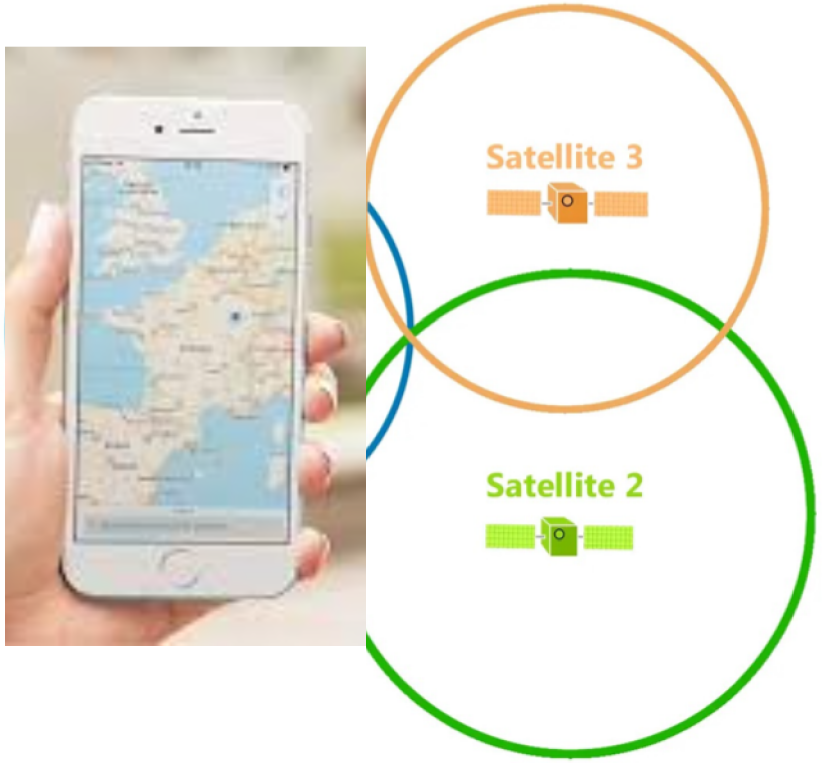
GPS: Where are you Located



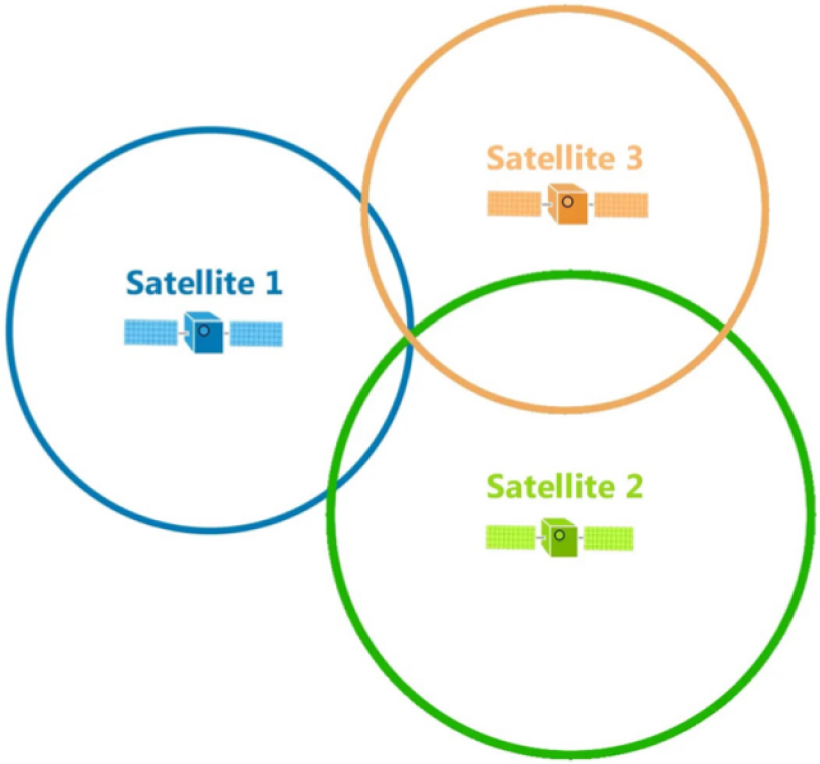
GPS Global Positioning System

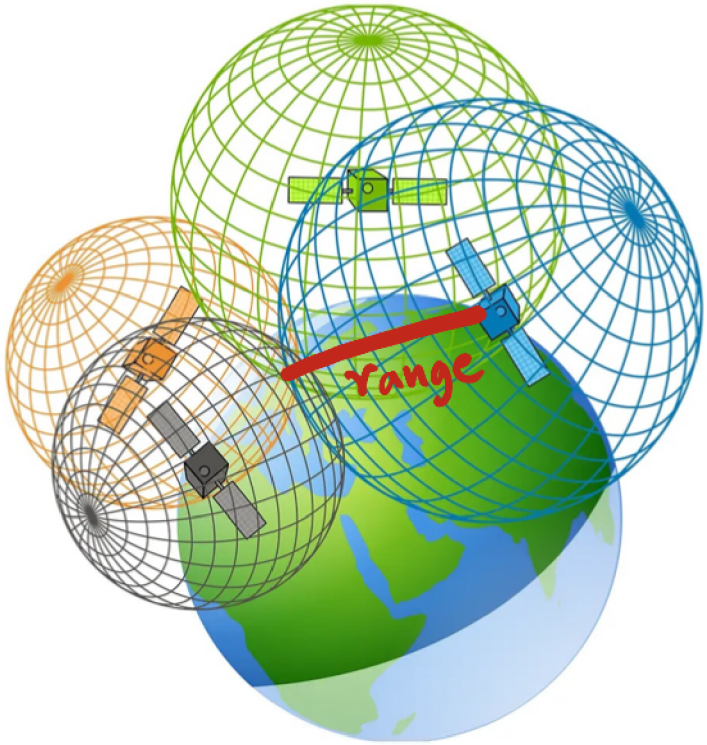
- Uses satellites that communicate with receivers. A receiver might be in your smartphone, car, or computer
- Receivers get signals from satellites. The signal usually contains the time from the satellites' "atomic clock".
- Receiver figures out how long it took the signal to arrive from the the satellite. It knows the speed of the signal (speed of light about 300,000,000 m/s).
- It computes:

  Distance = signal speed x signal time
- GPS receiver needs signals from at least three satellites to find its position - using a process called **Trilateration**.



GPS Global Positioning System



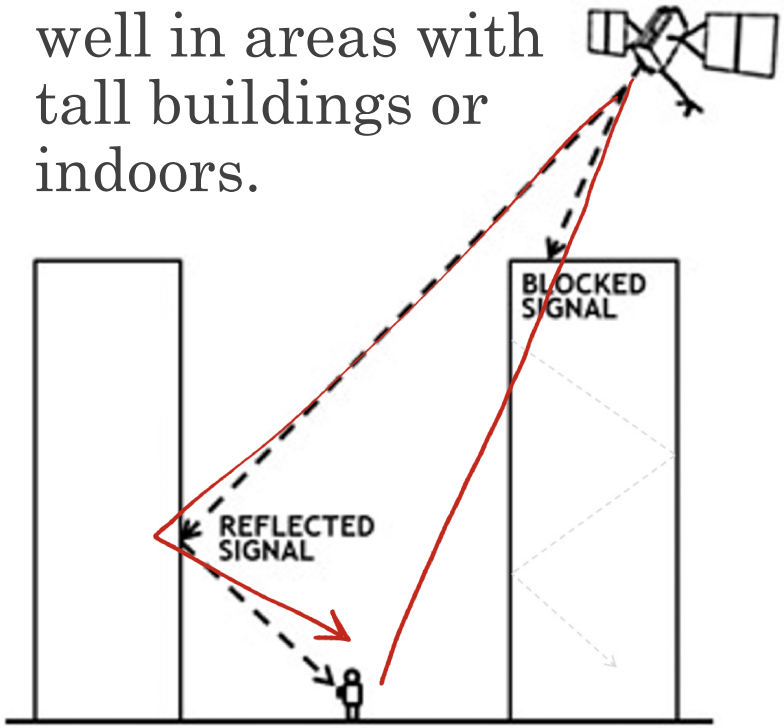


GPS Satellites

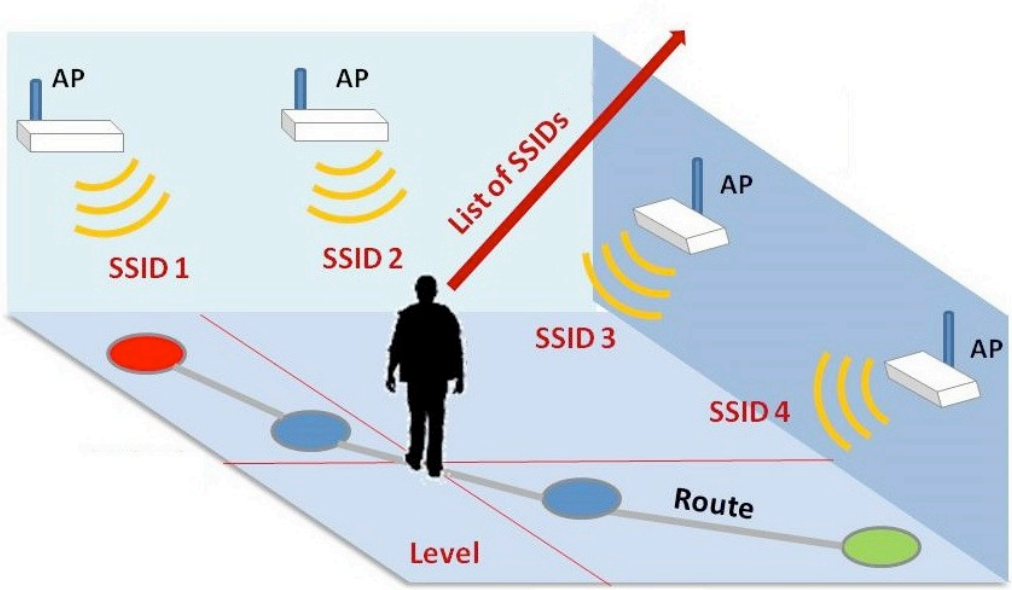
- Works with the help of a system of satellites. There are over 30 satellites used for GPS, orbiting over 16,000 miles (26,000km) above the Earth!
- Control centers on the ground make sure that the satellites operate properly.
- Currently, a GPS-enabled smartphone usually knows your location within about 5 metres.

Issues with GPS

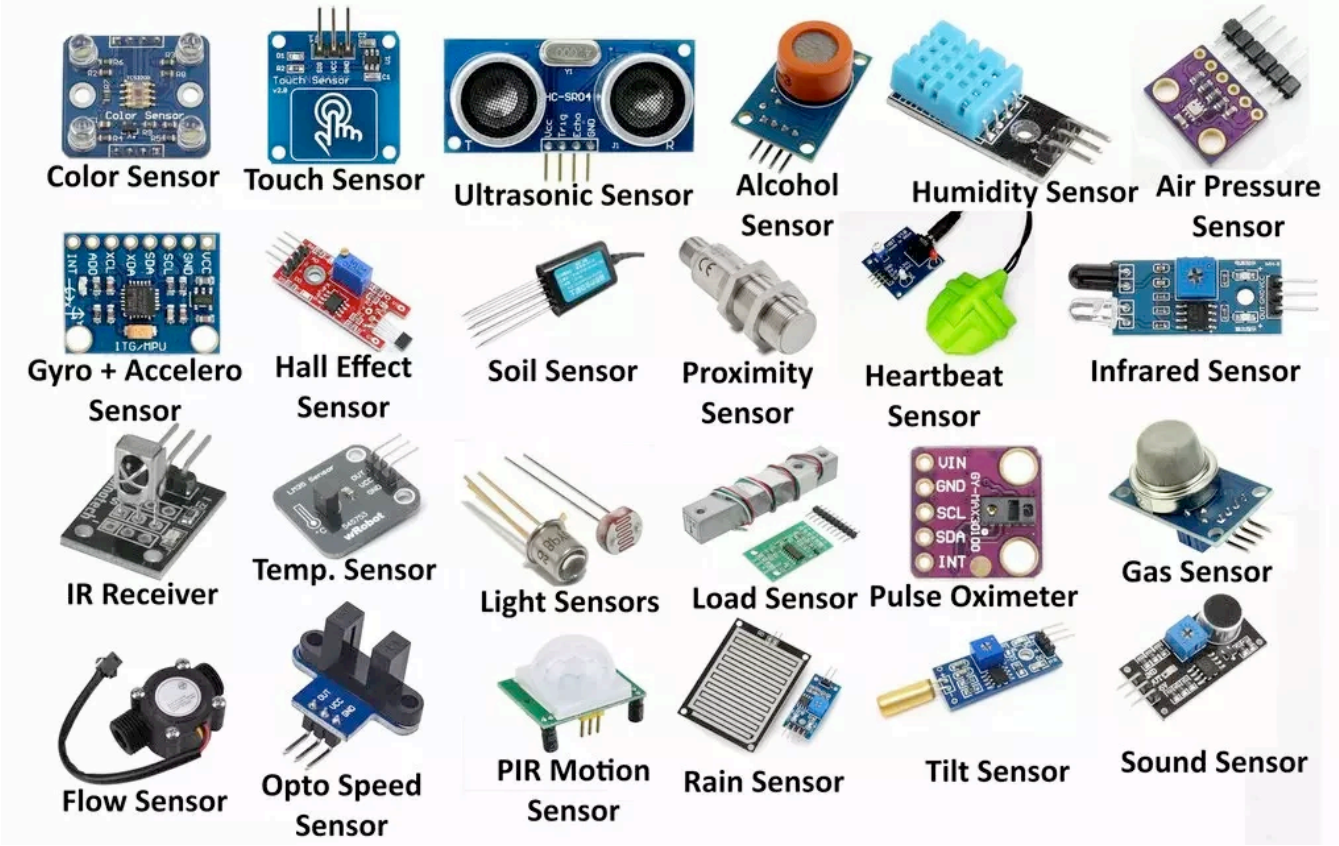
- GPS does not work well in areas with tall buildings or indoors.



- A possible solution is using WiFI access points instead



All Sorts of Sensors



Terminology You Should Know from These Slides

- LIDAR
- Emission and reflection
- 3-D point cloud
- Infrared radiation
- Thermal imaging
- Night vision cameras
- Microphone
- Diaphragm
- Inertial measurement unit (IMUs)
- Accelerometer, Gyroscope, Magnetometer
- **MEMS** (Micro ElectroMechanical Systems)
- GPS Global Positioning System
- Trilateration

Concepts You Should Know from These Slides

- How LIDAR works
- Applications of LIDAR
- Infrared imaging vs. thermal imaging
- How microphones work
- Applications of IMU
- How GPS works
- Possible issues with GPS
- Different types of sensors