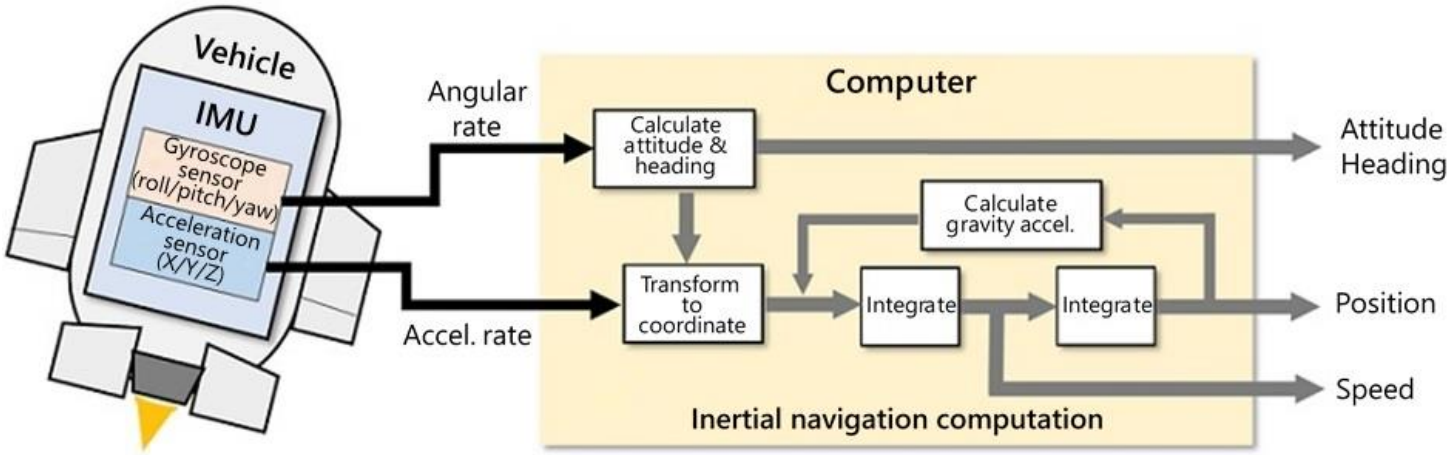
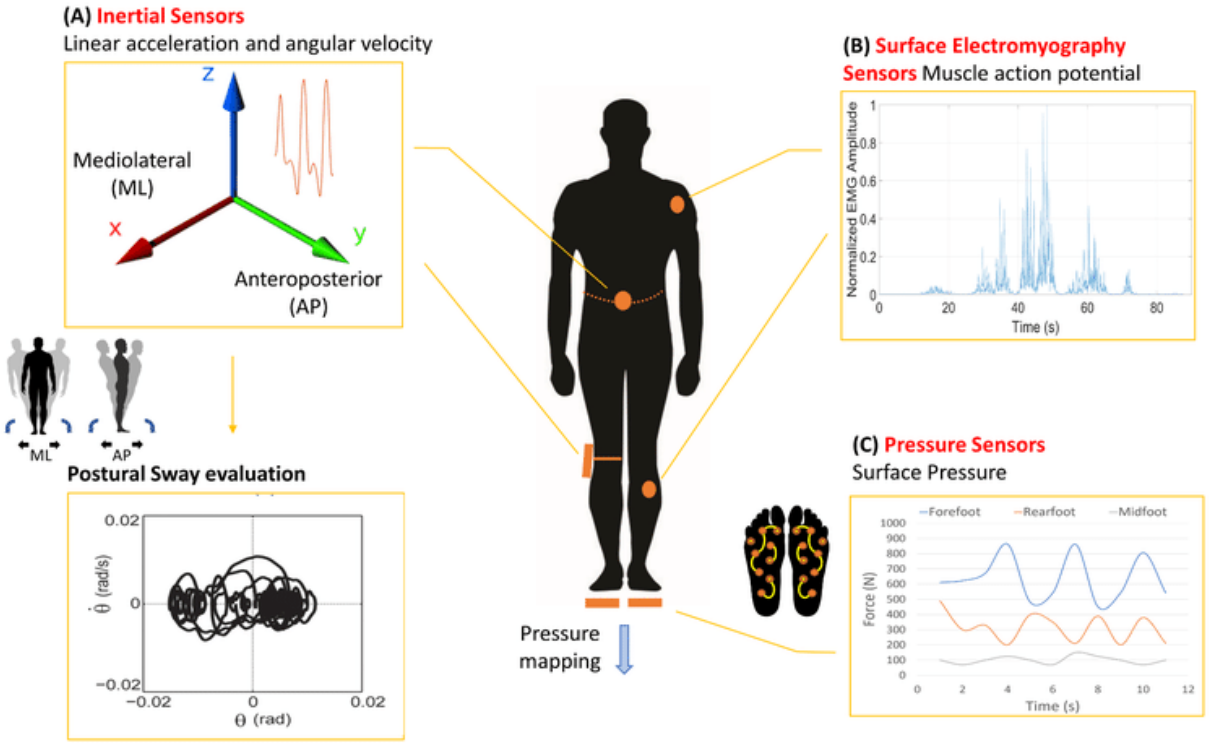
Inertial Sensors

- Inertial sensors are the combination of accelerometers, gyroscopes, and sometime magnetometers and other sensors that are used to measure object's parameters such as velocity, acceleration, orientation, gravitational forces, and others.
- These sensors are **inertial** because their measurements are based on a reference system.

- Types of inertial sensors:
  - Accelerometers
  - Gyroscopes
  - Global positioning system (GPS)

Inertial sensors

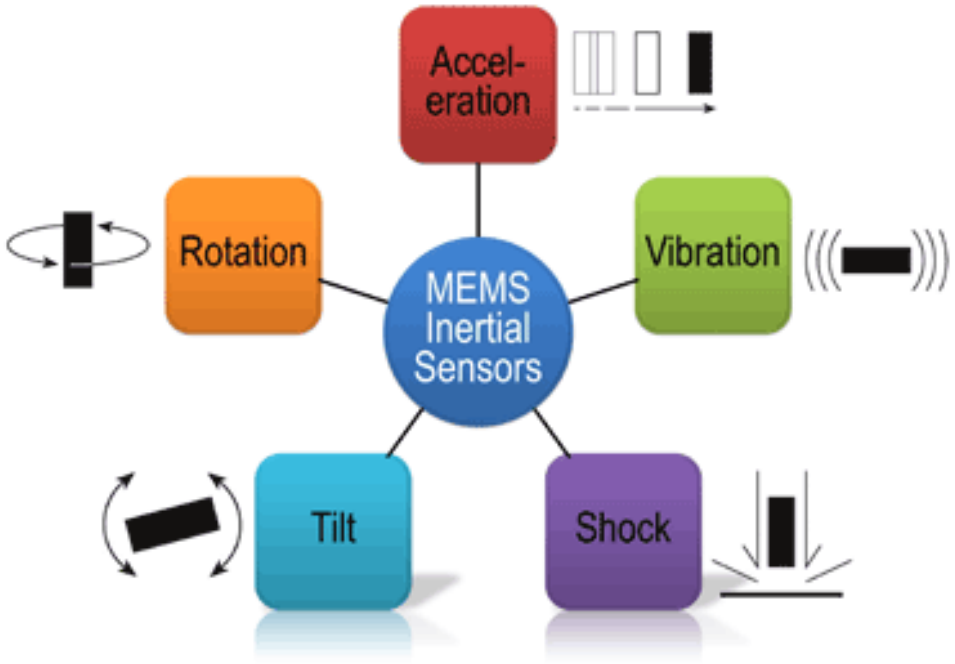


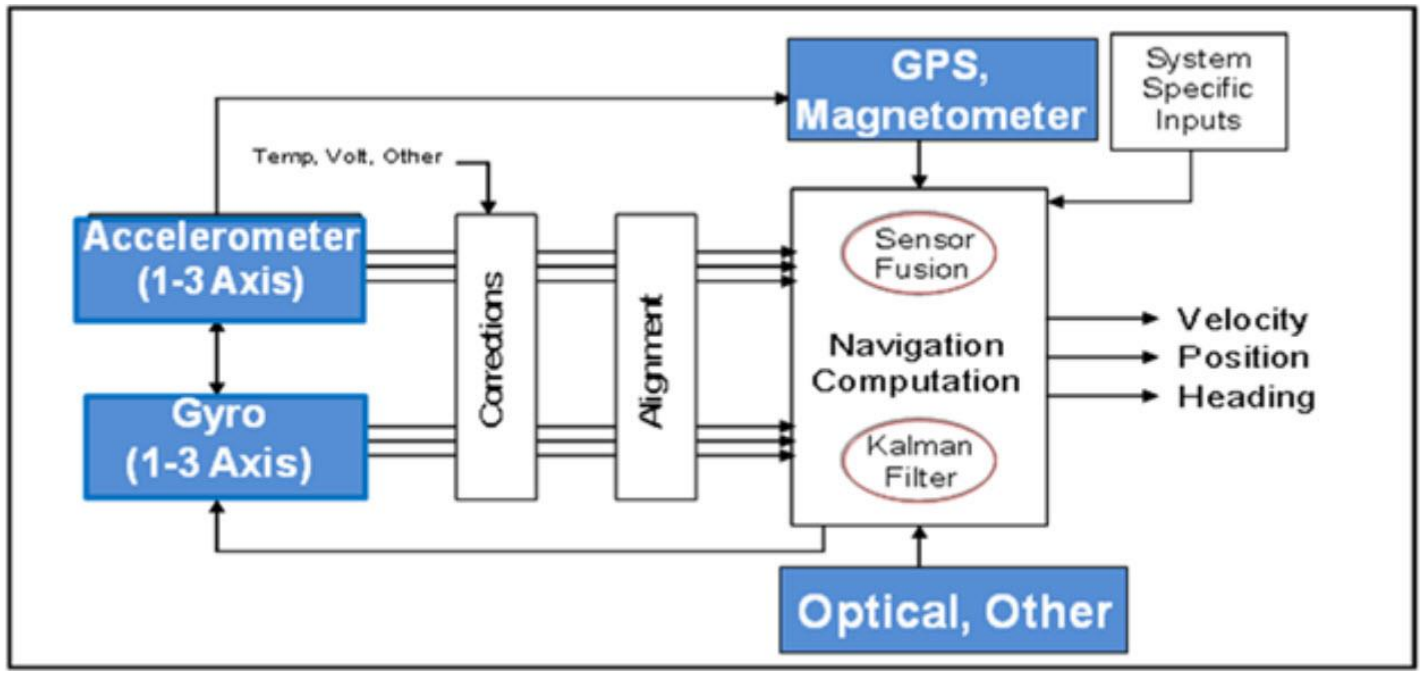


https://www.tkk-air.co.jp/english/aerospace/inertial-sensors.html

https://www.researchgate.net/figure/Wearable-technologies-Three-main-types-of-wireless-sensors-are-available-for-motion_fig2_342041596

MEMS (Micro-Electromechanical Systems)

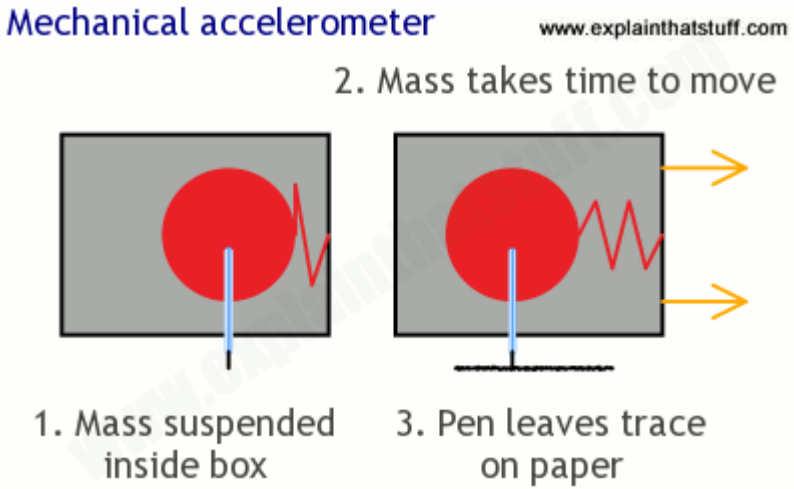


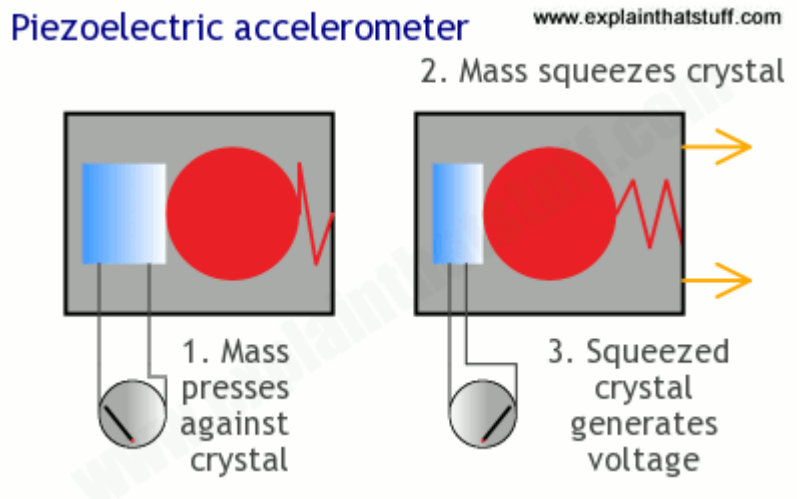


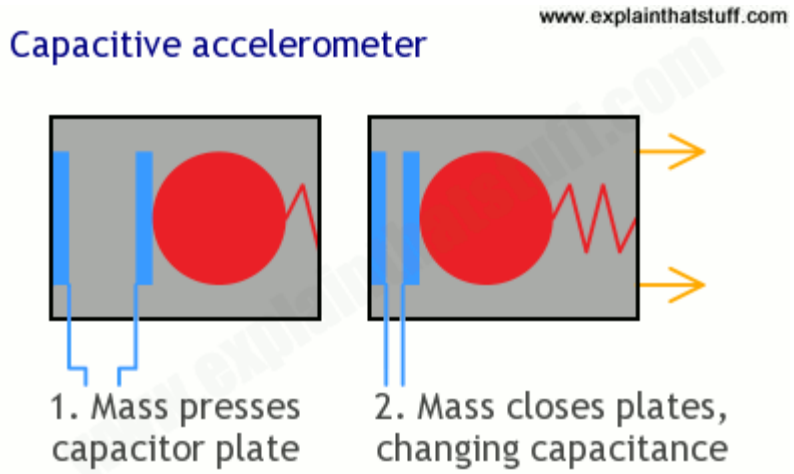
https://www.electronicproducts.com/improving-control-with-mems-inertial-sensors/

Types of Accelerometers

Accelerometers are used to detect translational motion in either two or three dimensions.





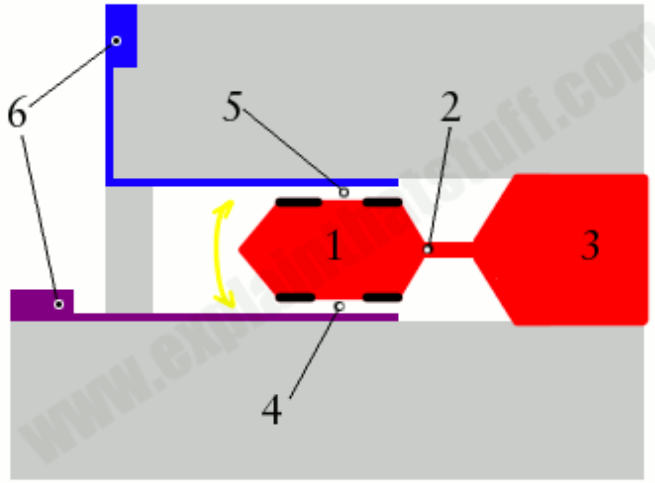


https://www.explainthatstuff.com/accelerometers.html

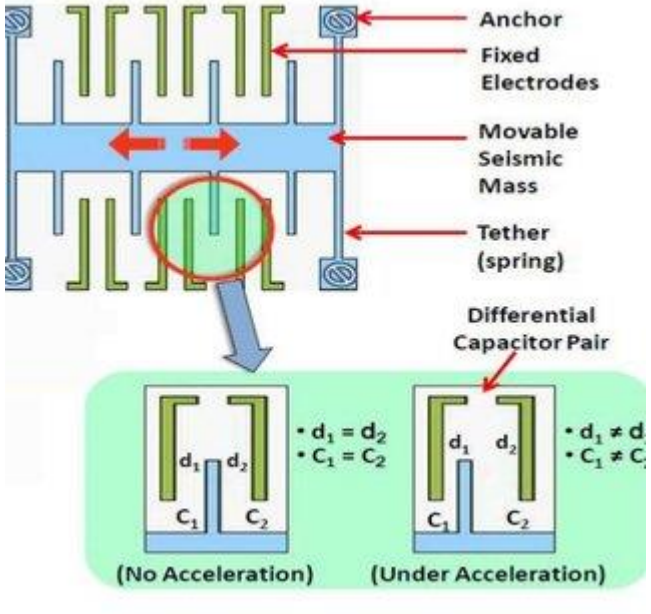
Types of Accelerometers

MEMS (micro electromechanical systems) accelerometers

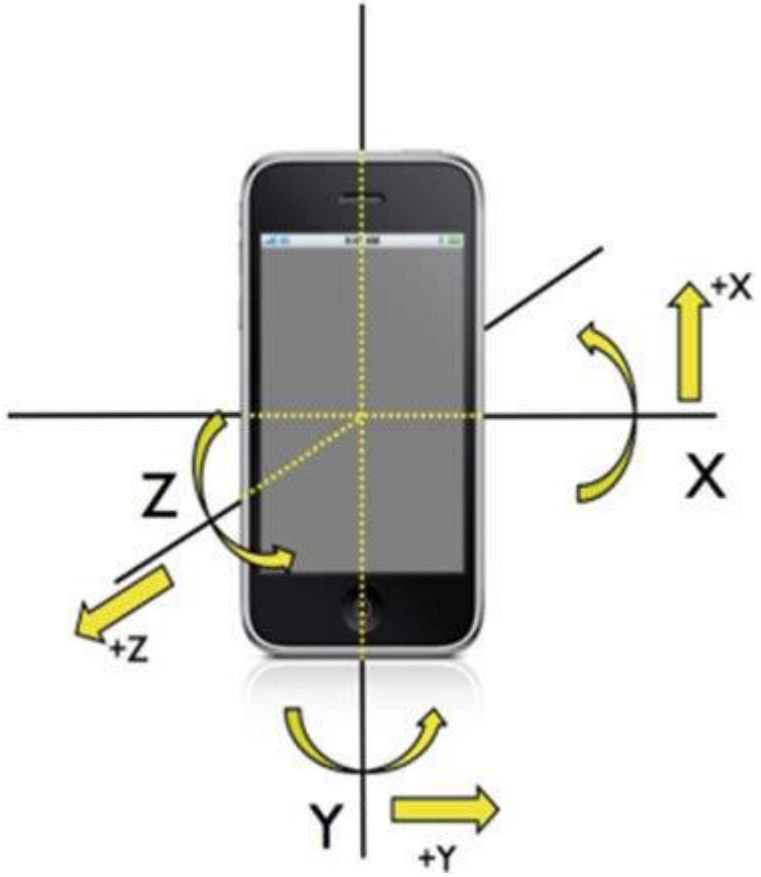
(1) A red electrode has enough mass to move up and down very slightly when it is titled or moved.
(2) The electrode is supported by a tiny cantilever
(3) There is an electrical connection from cantilever to electrode to wire it to a circuit
(4) There is a second electrode (purple) below the first; these two electrodes work as a capacitor. When the red electrode moves up and down with the mass, this changes the capacitance between them.
(5) A third electrode (blue) is on the other side of the mass and works the same way as the first pair.
(6) The electrodes are connected to a bigger chip which is then wired to an external circuit.

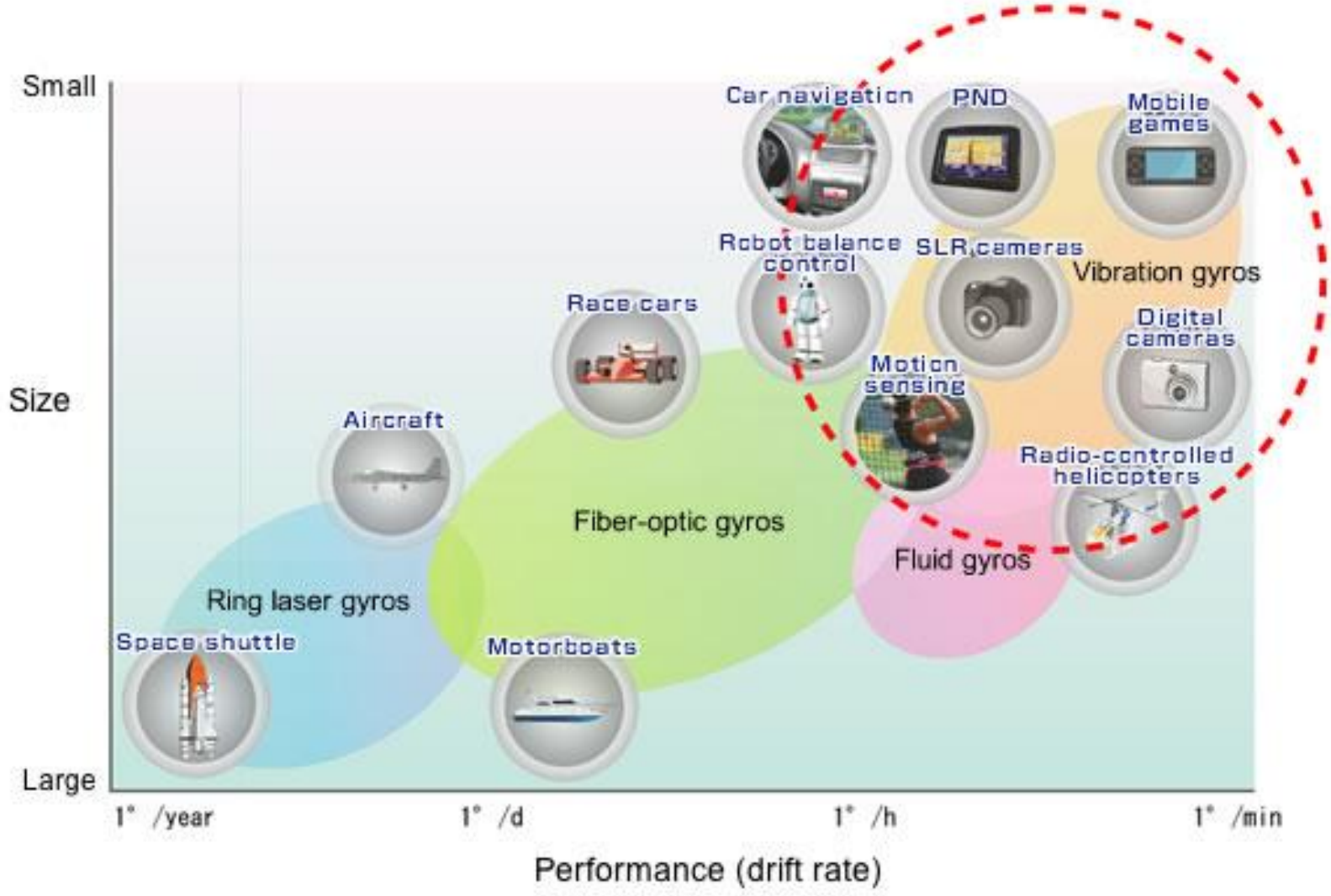


www.explainthatstuff.com

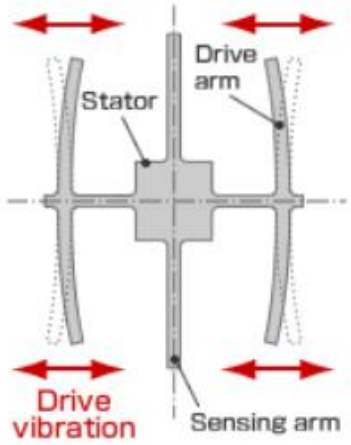


Gyroscopes

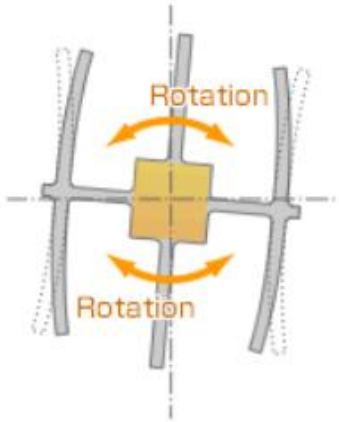




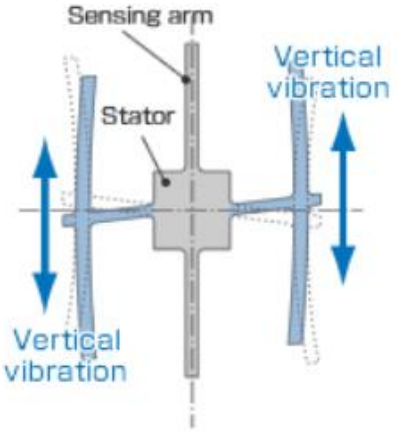
Gyroscopes are used to detect rotational (angular) motion in two or three dimensions.



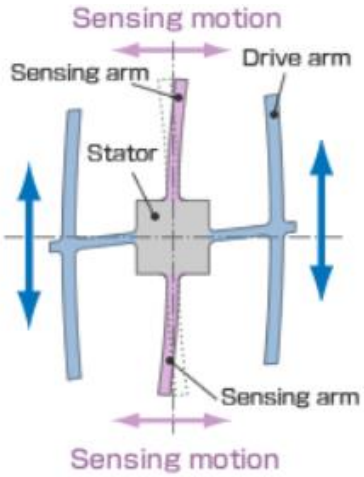
1. Normally, a drive arm vibrates in a certain direction.



2. Direction of rotation



3. When the gyro is rotated, the Coriolis force acts on the drive arms, producing vertical vibration.

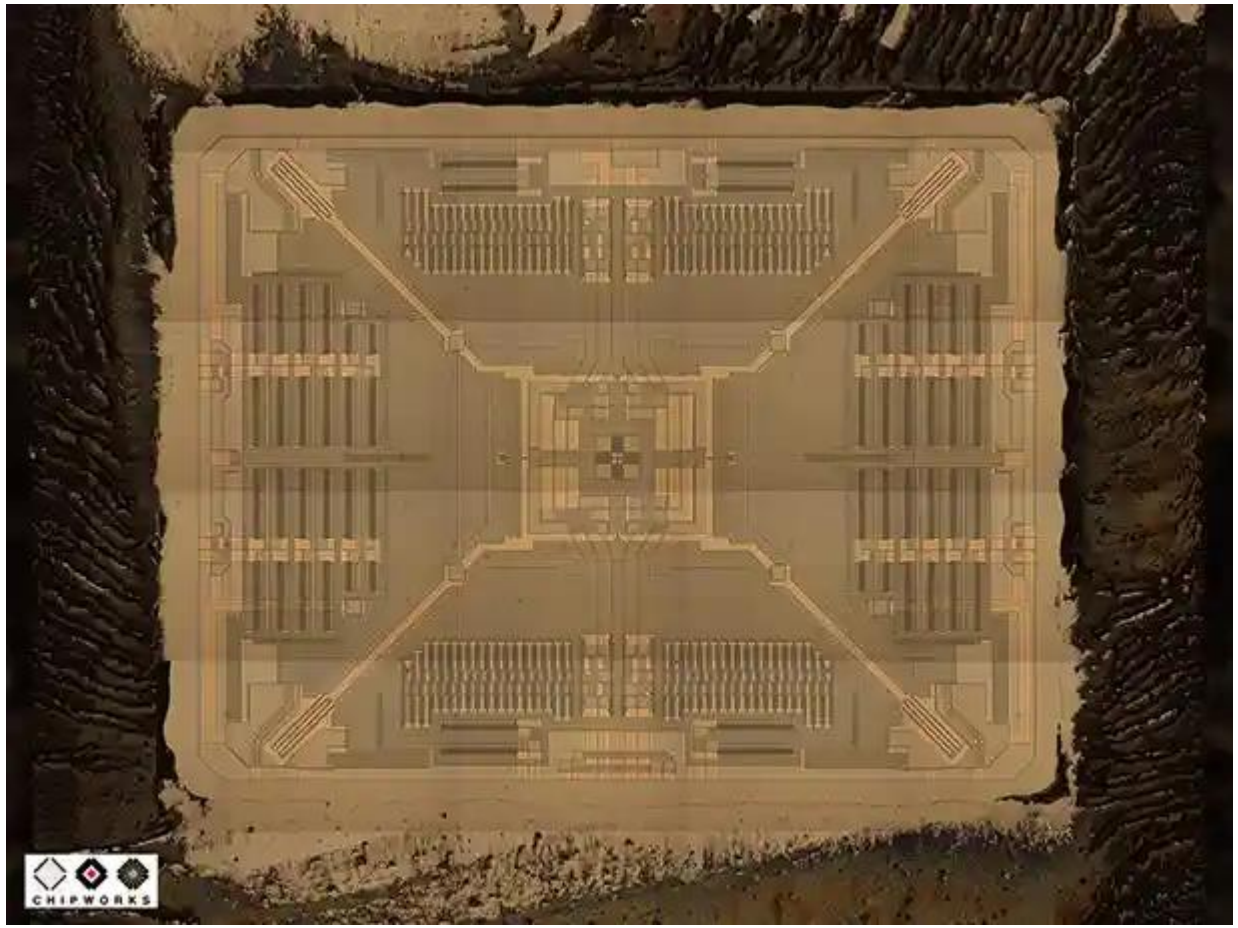


4. The stationary part bends due to vertical drive arm vibration, producing a sensing motion in the sensing arms.

5. The motion of a pair of sensing arms produces a potential difference from which angular velocity is sensed. The angular velocity is converted to, and output as, an electrical signal.

https://www5.epsondevice.com/en/information/technical_info/gyro/

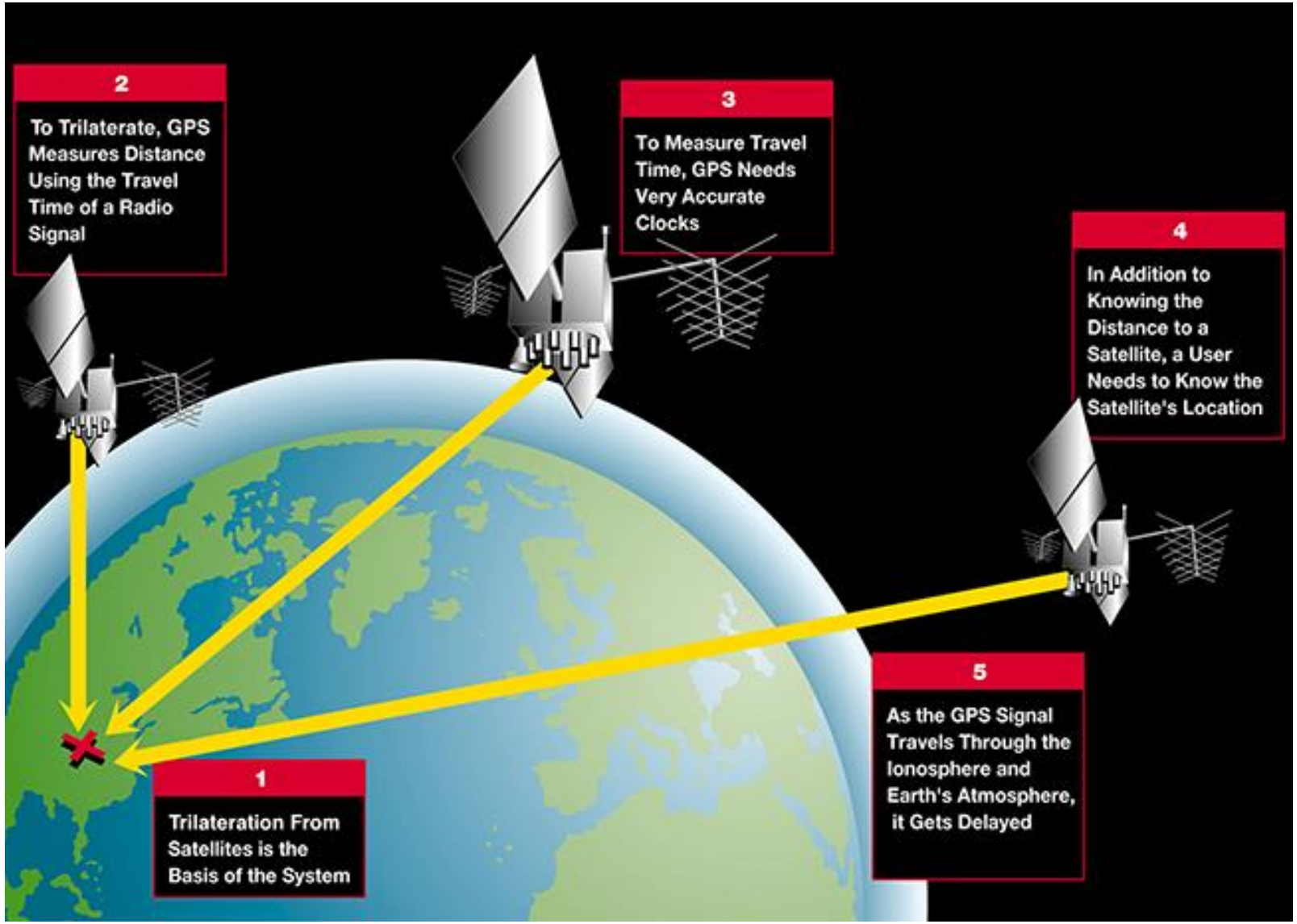
Gyroscopes



The iPhone 4's gyroscope consists of a thin plate of etched silicon, called the "proof mass", which oscillates when you apply a voltage across a capacitative gap. (The gap is below the chip die)The masses are the quadrants on left and right of the picture. Tilt the chip and the masses move - generating a voltage change at the capacitative gap, and on "finger capacitors" (the fronds from the middle of the bottom and top).Careful interpretation by another chip of the electrical signal generated tells you how much and in which axes the gyro chip has been moved.

https://www.theguardian.com/technology/gallery/2010/jul/01/iphone-gyroscope-nanotechnology

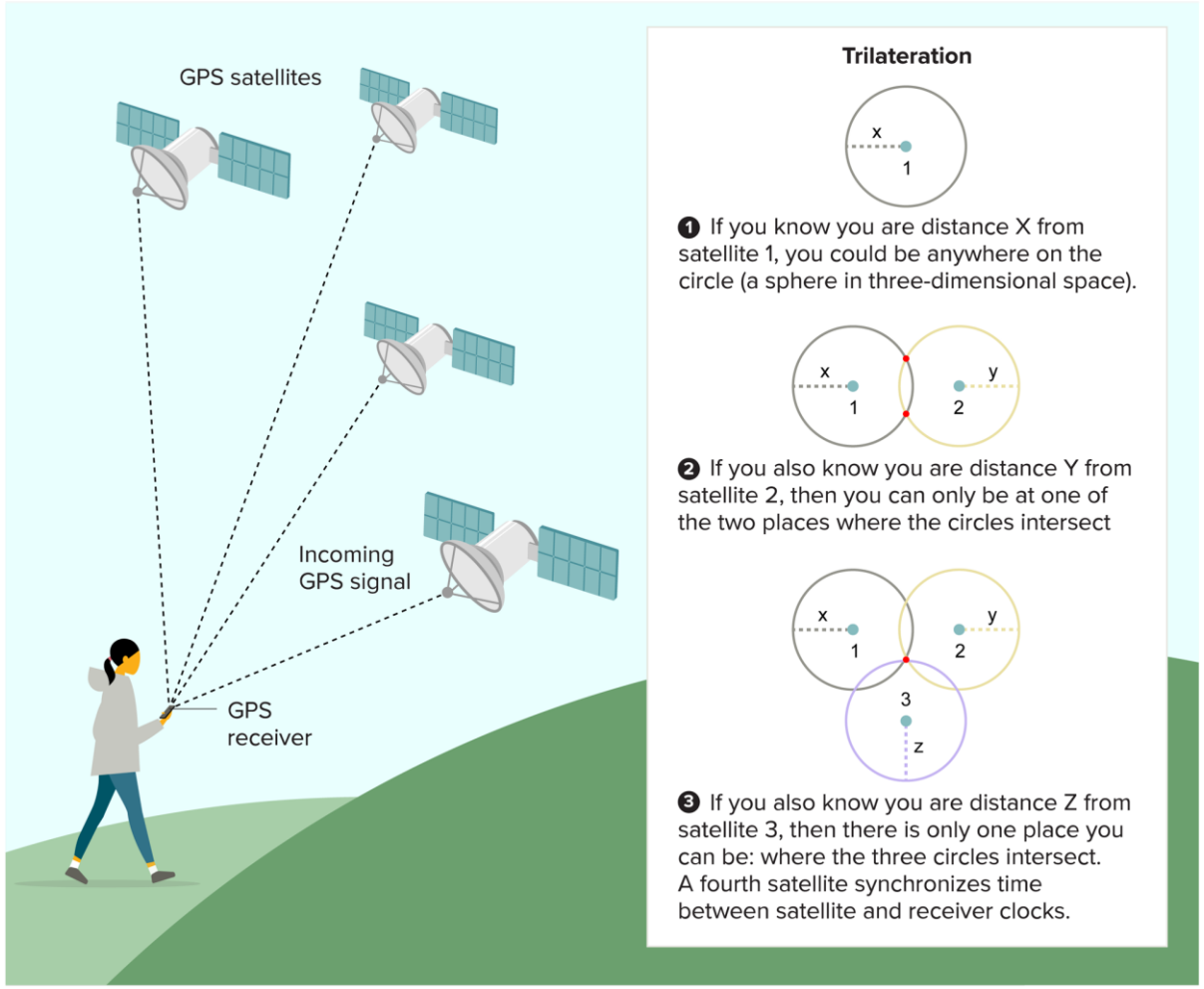
Global Positioning System



Global Positioning System

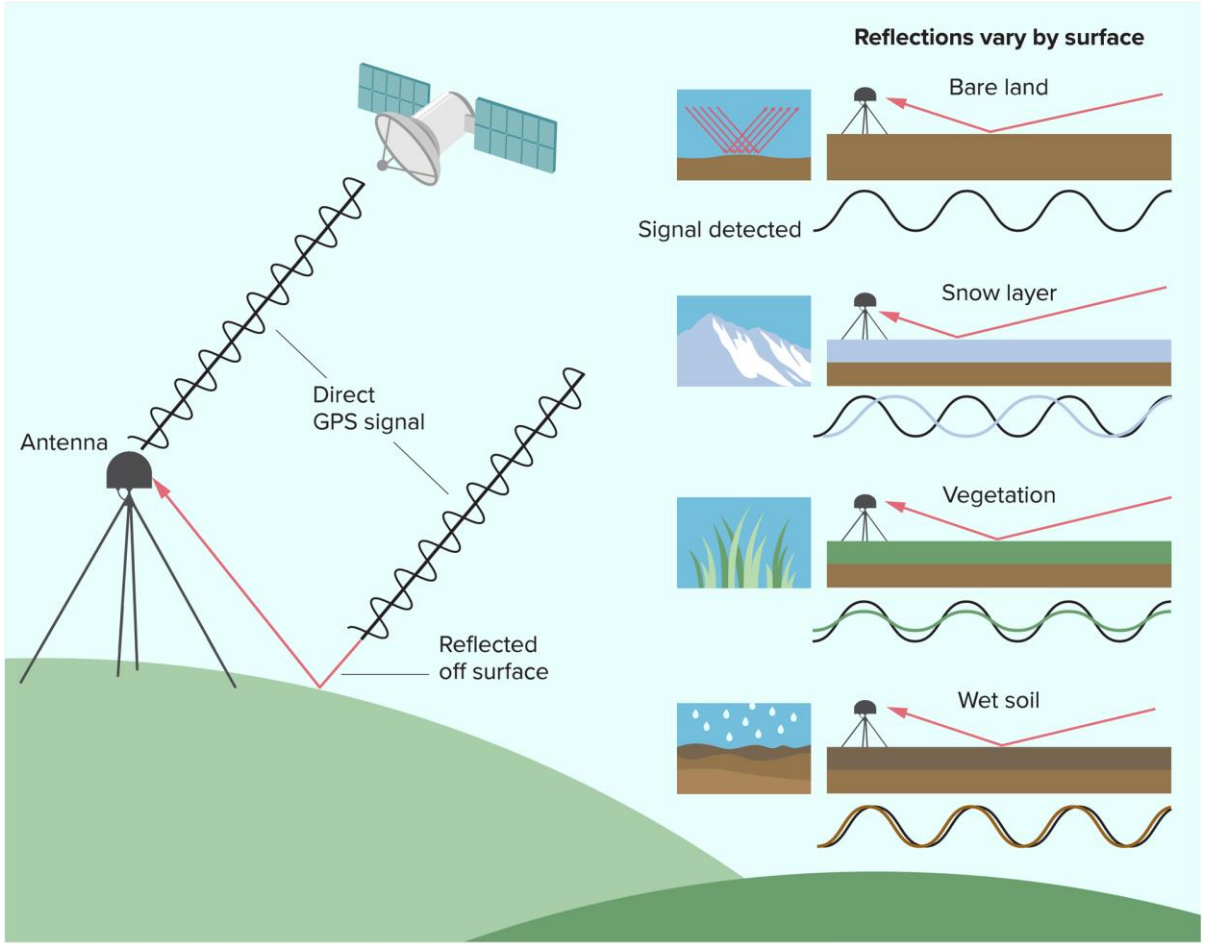
How GPS works

A GPS receiver, like the one in your smartphone, pinpoints its location on Earth's surface by analyzing its distance to three GPS satellites; a fourth satellite synchronizes clocks in the receiver and satellites.



SOURCE: UNAVCO KNOWABLE MAGAZINE

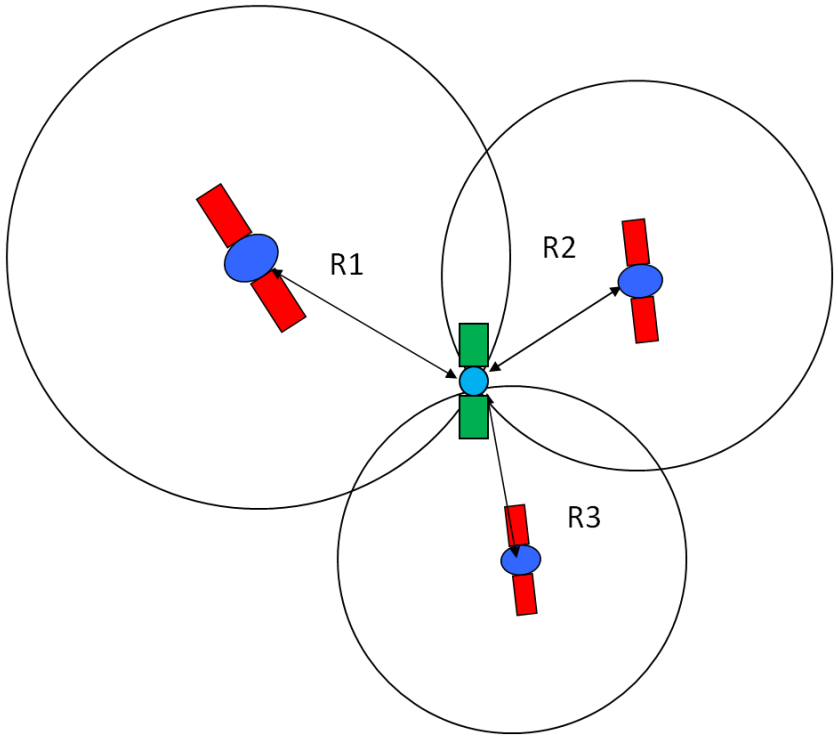
What reflected GPS signals can reveal



SOURCE: UNAVCO AND THE GPS REFLECTIONS RESEARCH GROUP KNOWABLE MAGAZINE

https://www.scientificamerican.com/article/gps-is-doing-more-than-you-thought/

Global Positioning System



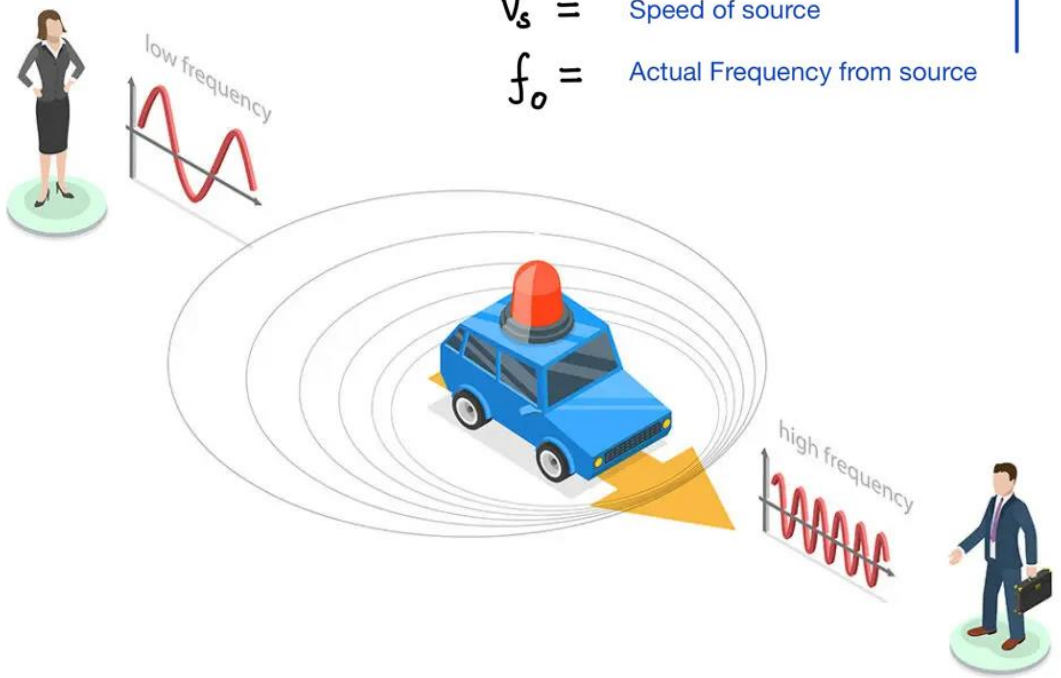
Triangulation is used to determine position.

https://trakkitgps.com/how-gps-works/

$$f = \left(\frac{c \pm v_o}{c \pm v_s}\right) f_o$$

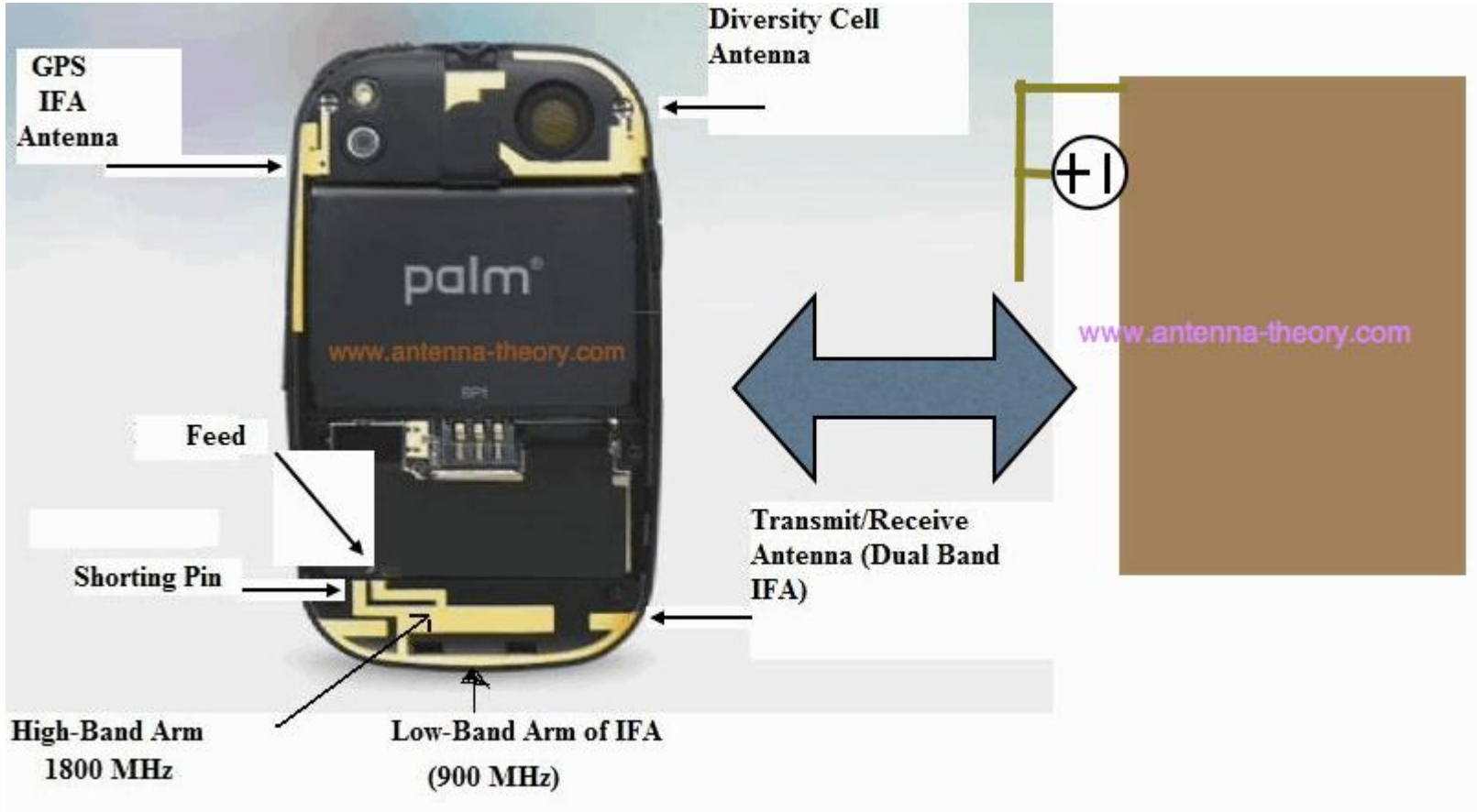
Sign depends if the observer & source are moving away or towards from each other

f = Apparent Frequency
c = Speed of sound
v_o = Speed of observer
v_s = Speed of source
f_o = Actual Frequency from source

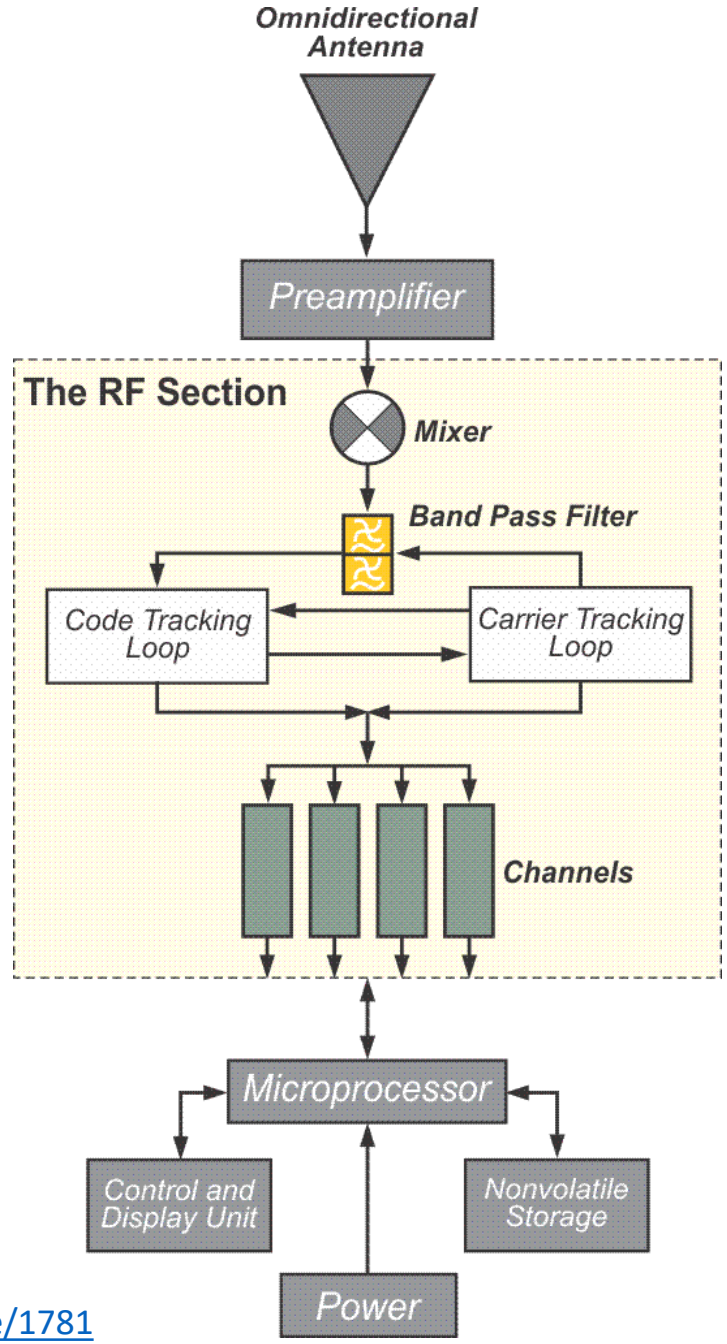


The **Doppler Effect** is used to determine speed or velocity.

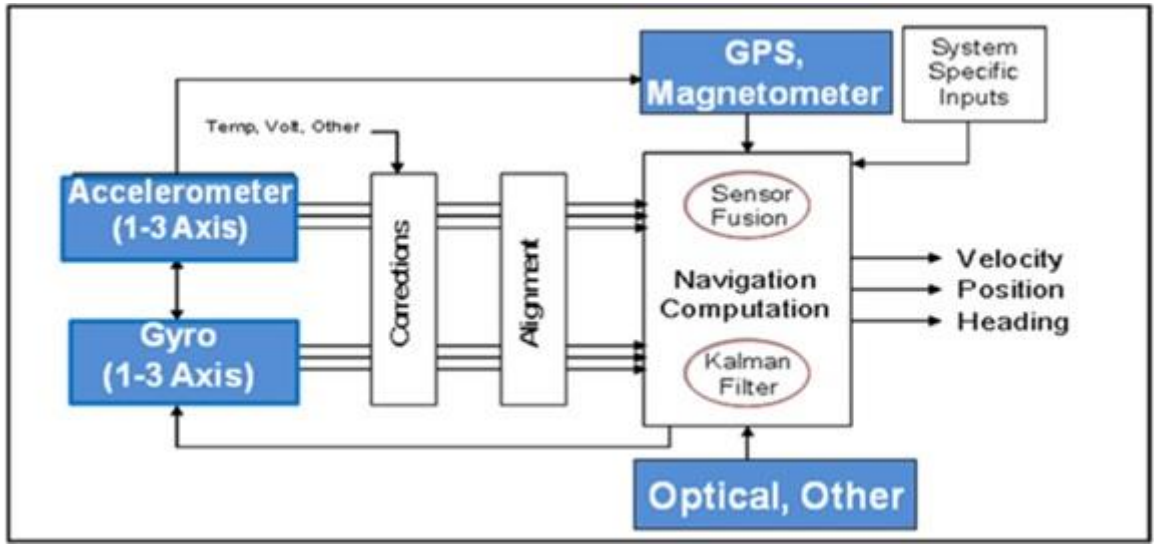
Global Positioning System

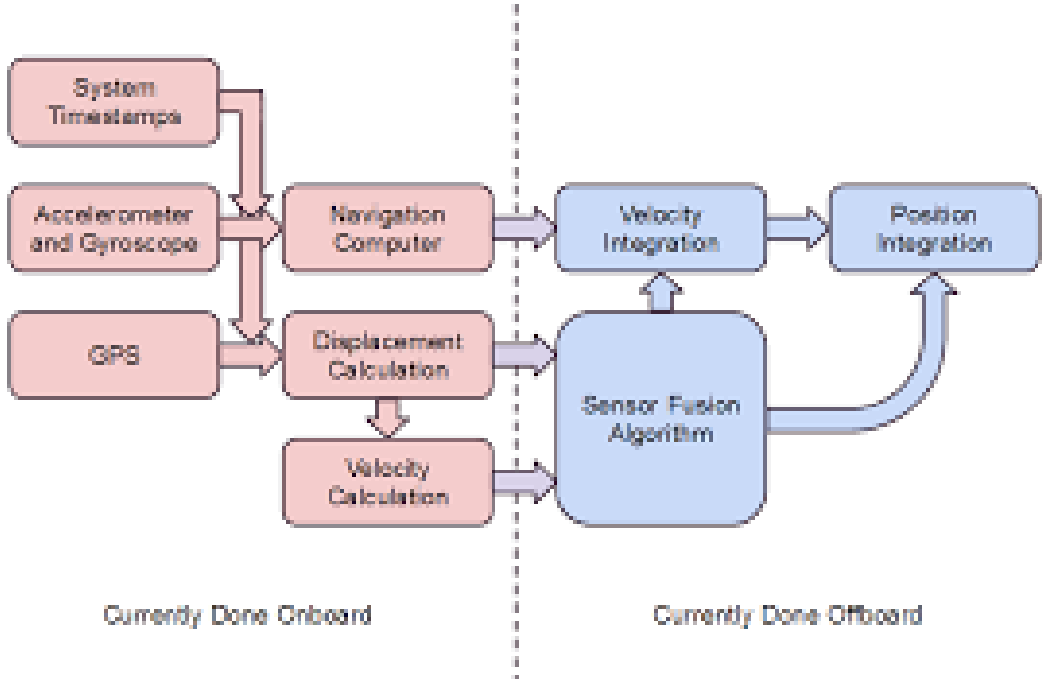


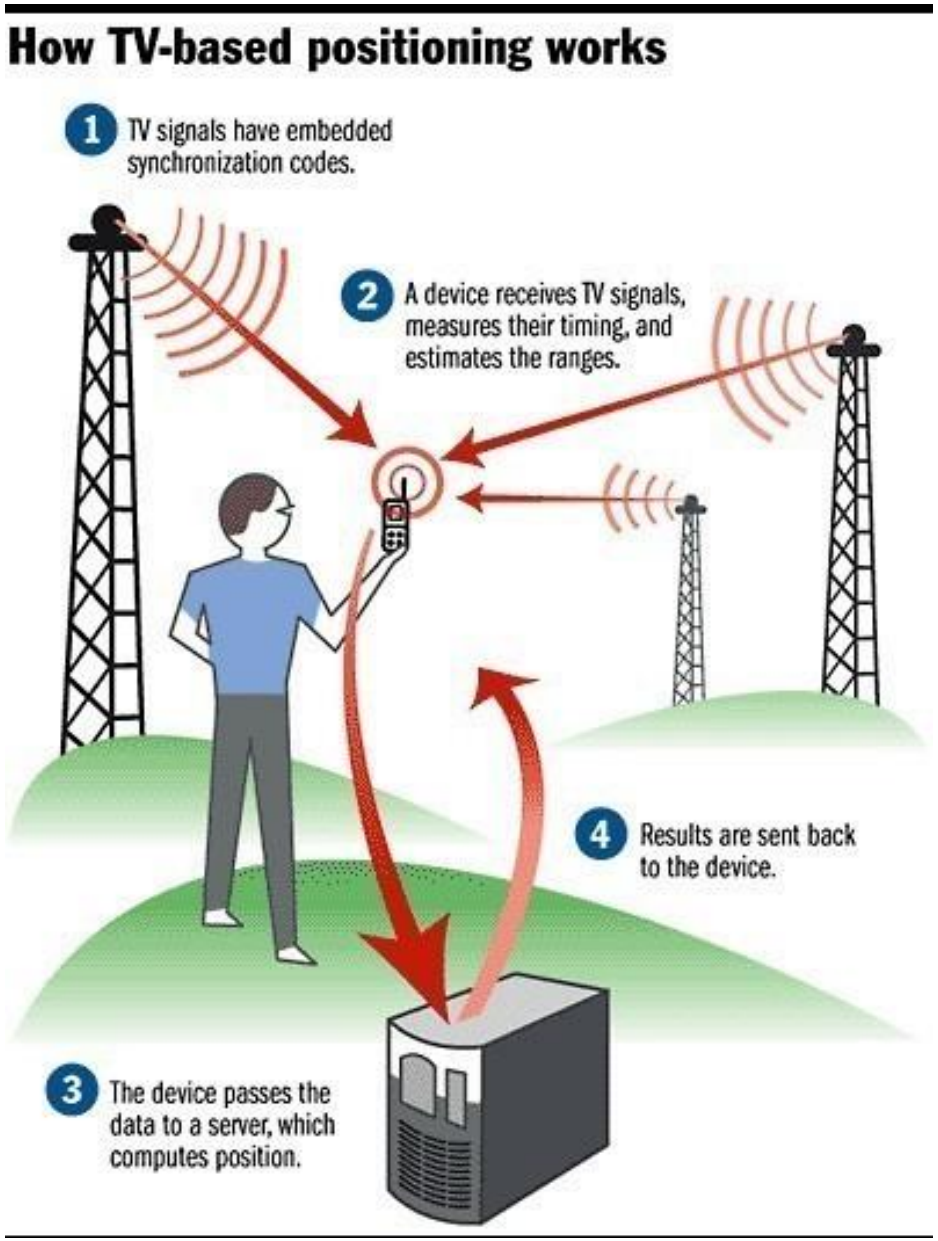
https://www.antenna-theory.com/design/gps.php



https://www.e-education.psu.edu/geog862/node/1781







https://www.androidcentral.com/how-does-gps-work-my-phone