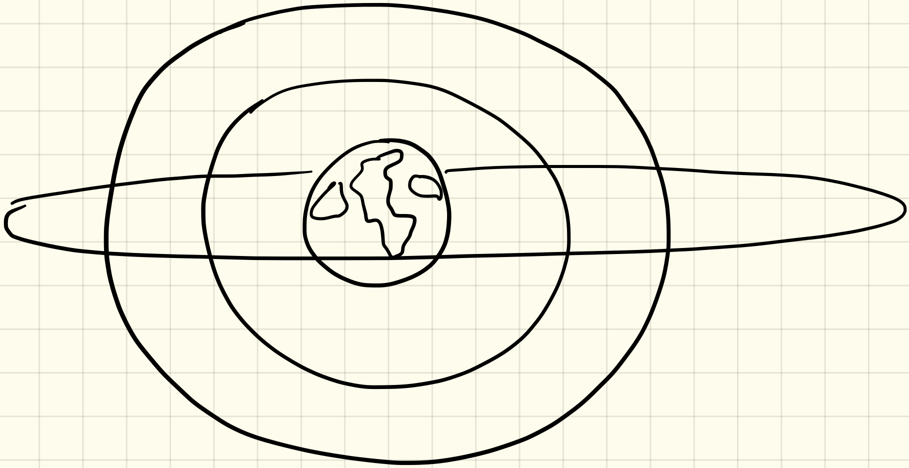
# ECE/CS 434 : GPS Basics

- Orbits



LEO : Low earth orbit
MEO : Medium earth orbit
GEO : Geostationary earth orbit

- USA → GPS
  EU →
  Russia →
  Japan →
  India →
  China →

- GPS → satellites around earth
  → mostly in MEO
    - → LEO too close ... needs ... satellites for earth coverage
    - → GEO too far ...

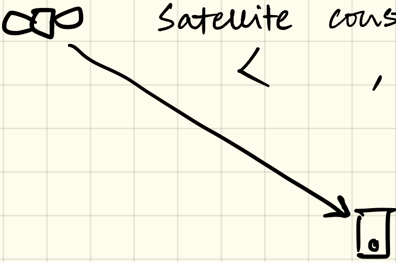
## Navigation Message

being sent continuously from satellite

- ↳ Why so low? Because =
- ↳ Note : WiFi bitrate ≈

Satellite constantly sending :

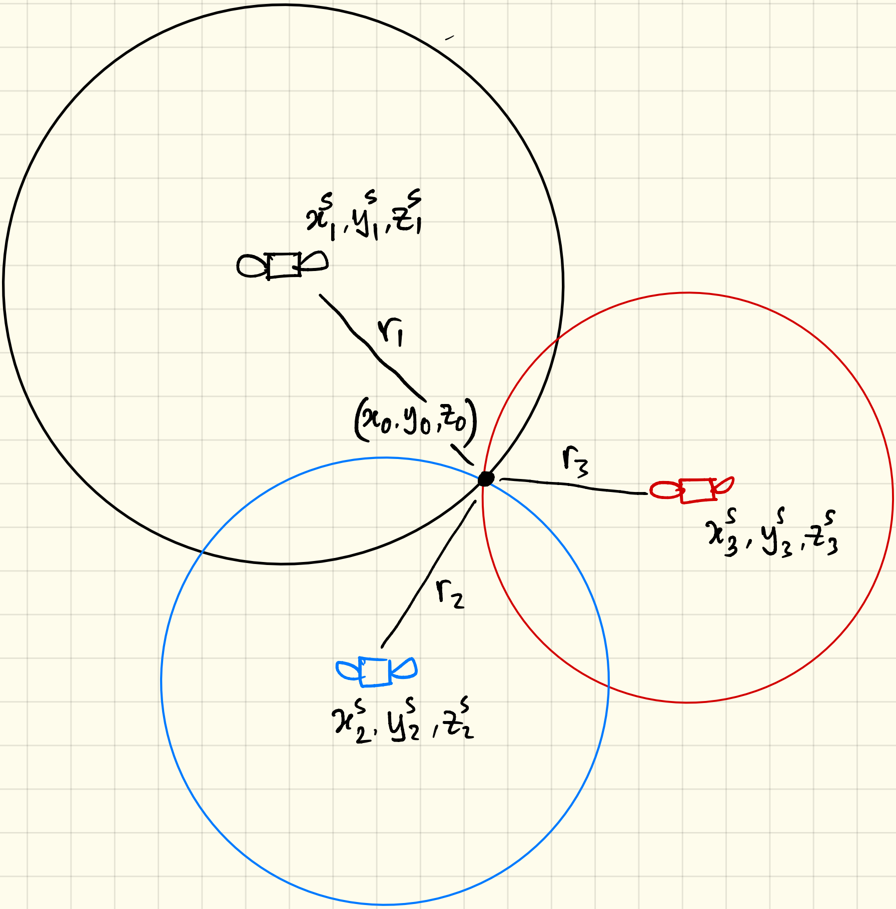
< , >



All GPS satellite clocks are synchronized. How?

- → (Hawai, Colorado, Atlantic, Indian ocean, and Pacific)
- → Centers ingesting GPS signals, computing satellite locations and clocks, and these corrected estimates to satellites to adjust each clock and ephemeris
- → Infrequent needed
  - ↳ like more satellite location in case of

## ⑦ GPS localization : Basic idea.



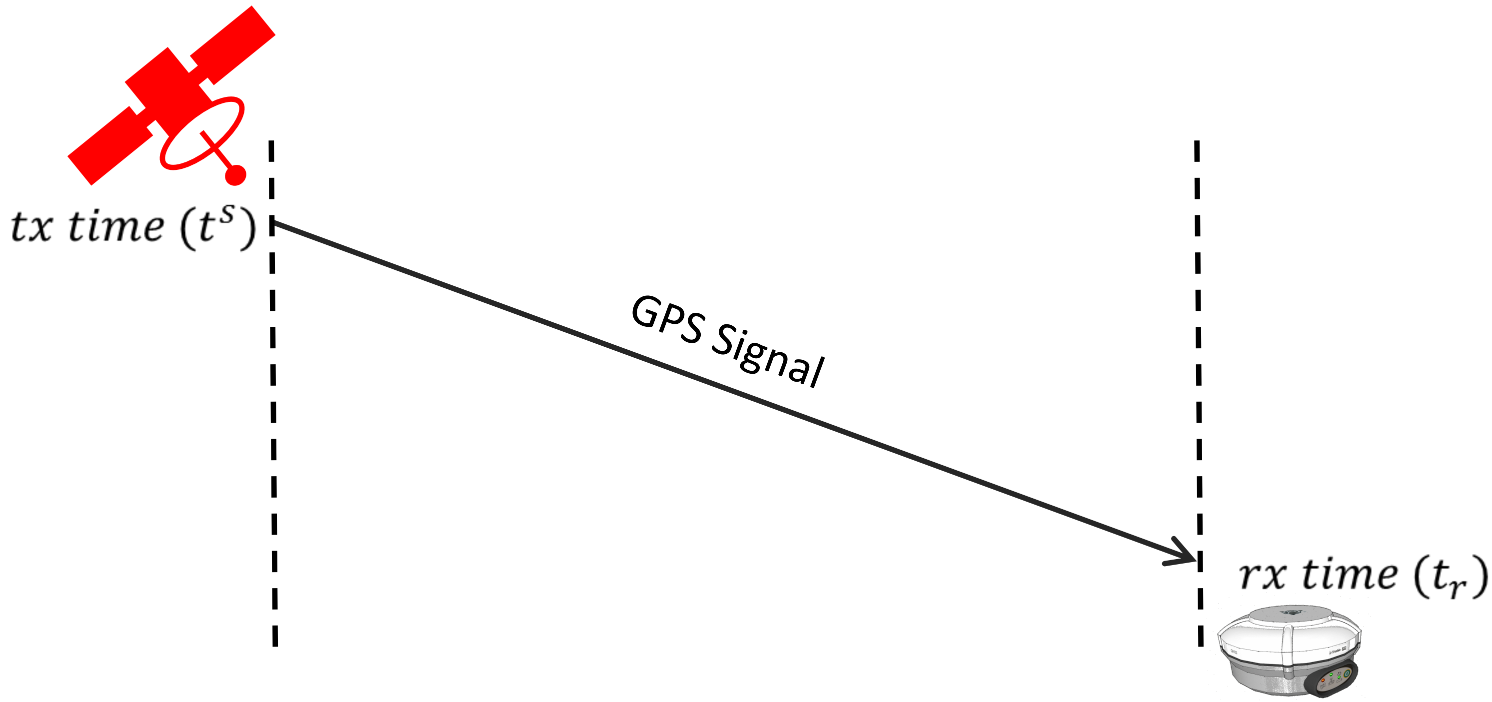

(a) Receiver from itself to each satellite , $r_i$

(b) Formulates as , where $\bar{x} = \begin{bmatrix} x_0 \\ y_0 \\ z_0 \end{bmatrix}$

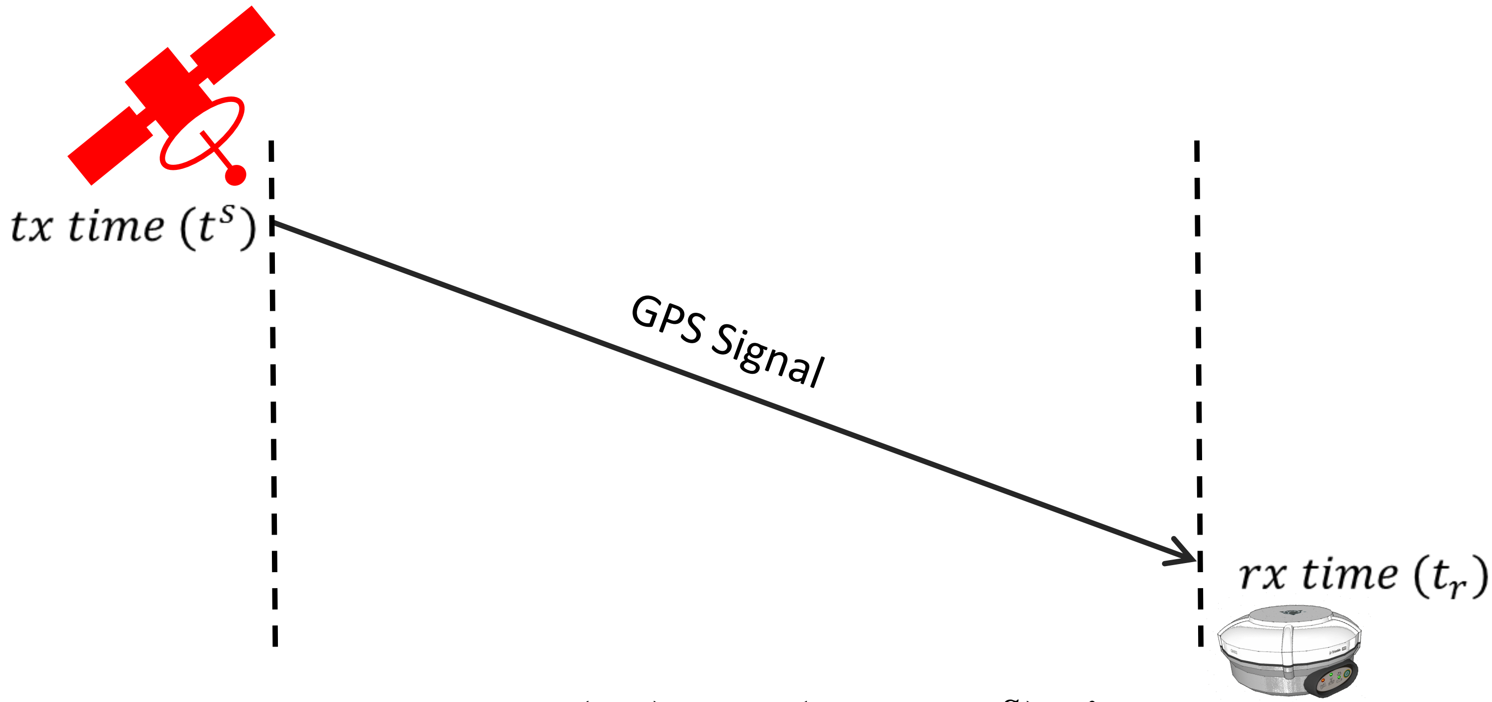
(c) $\bar{b}$ does not ... thus needs to solve

(d) GPS receiver's clock also gets

# Basic GPS Localization

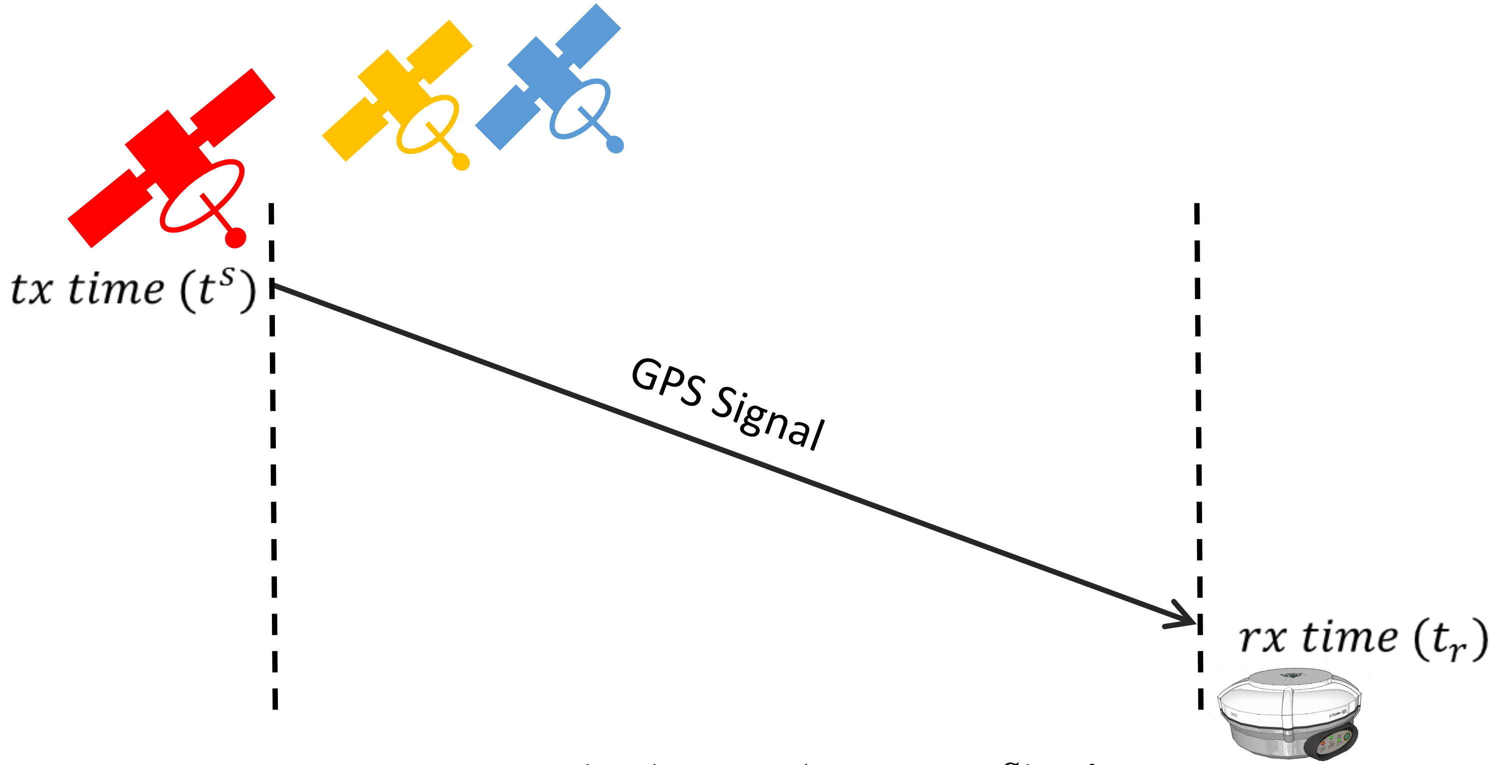


# Basic GPS Localization




$$Range(R) = (t_r - t^s) * c$$

# Basic GPS Localization




$$Range(R) = (t_r - t^s) * c$$

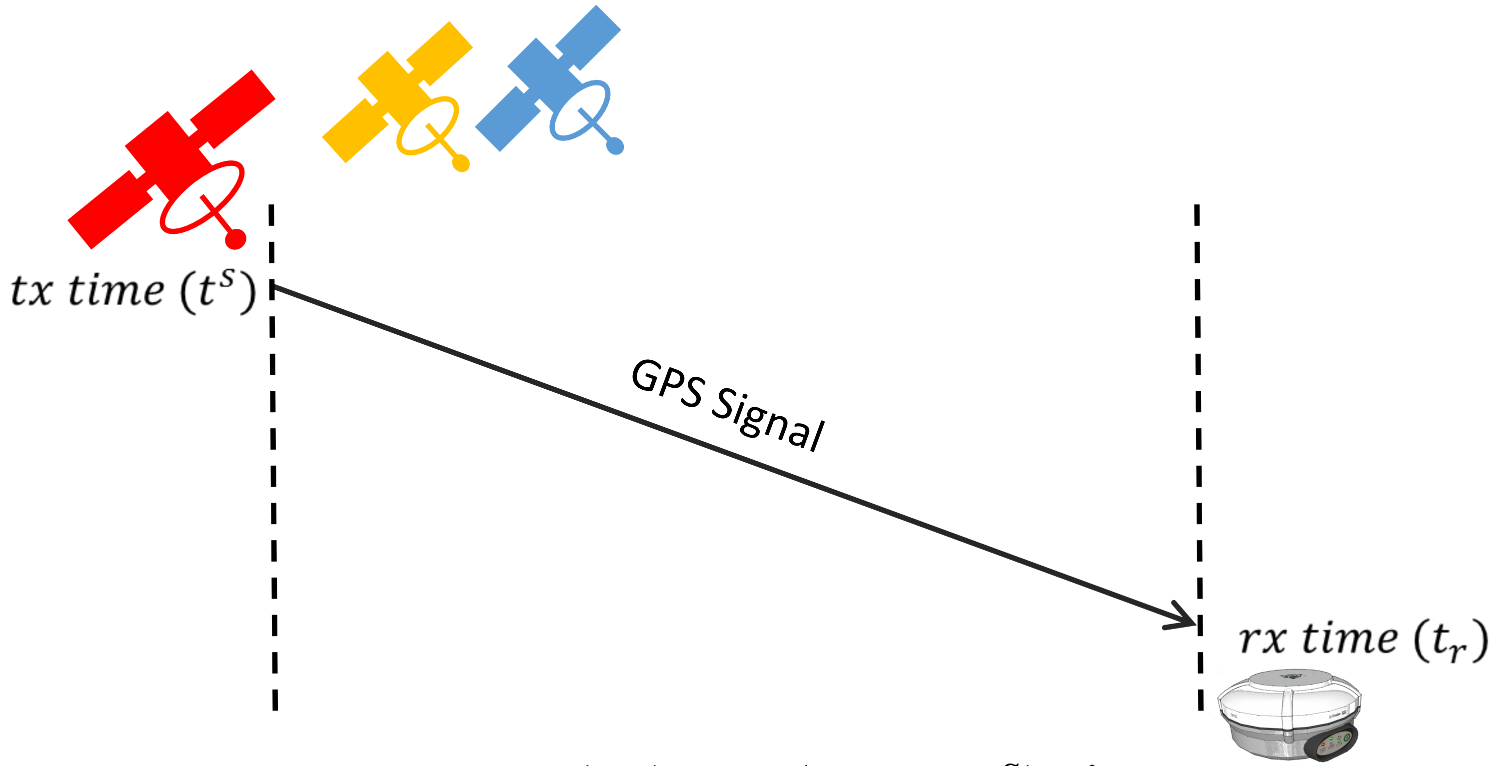
However, 3D location needs 3 equations … hence, use 3 satellites

$$\sqrt{(x_1^s - x_0)^2 + (y_1^s - y_0)^2 + (z_1^s - z_0)^2} = (t_r^{(1)} - t_1^s) \quad \text{— ①}$$

$$\sqrt{(x_2^s - x_0)^2 + (y_2^s - y_0)^2 + (z_2^s - z_0)^2} = (t_r^{(2)} - t_2^s) \quad \text{— ②}$$

$$\sqrt{(x_3^s - x_0)^2 + (y_3^s - y_0)^2 + (z_3^s - z_0)^2} = (t_r^{(3)} - t_3^s) \quad \text{— ③}$$

# Basic GPS Localization

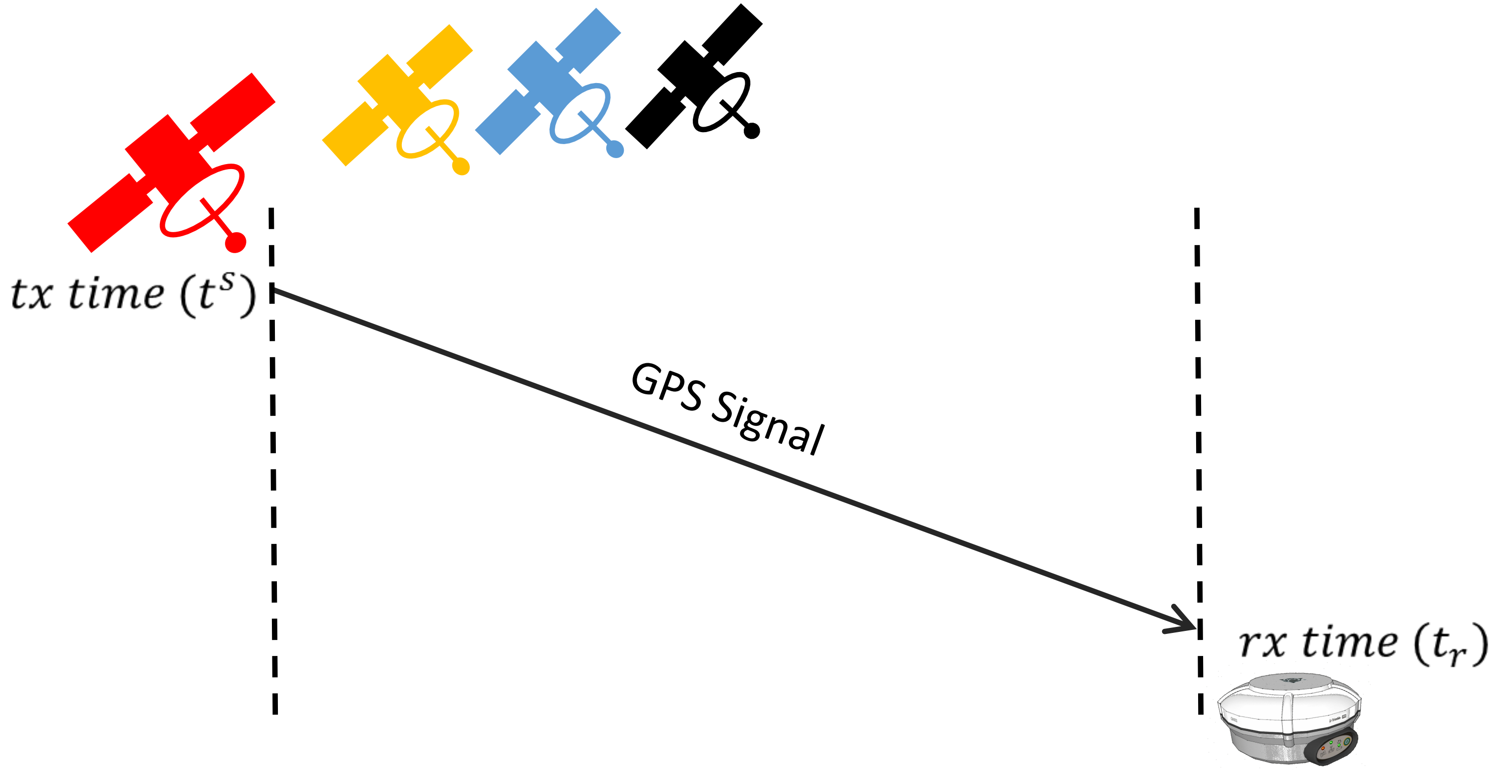



$$Range(R) = (t_r - t^s) * c$$

However, 3D location needs 3 equations … hence, use 3 satellites

$$\begin{bmatrix} \text{Satellite Geometry Matrix} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} R_1 \\ R_2 \\ R_3 \end{bmatrix}$$

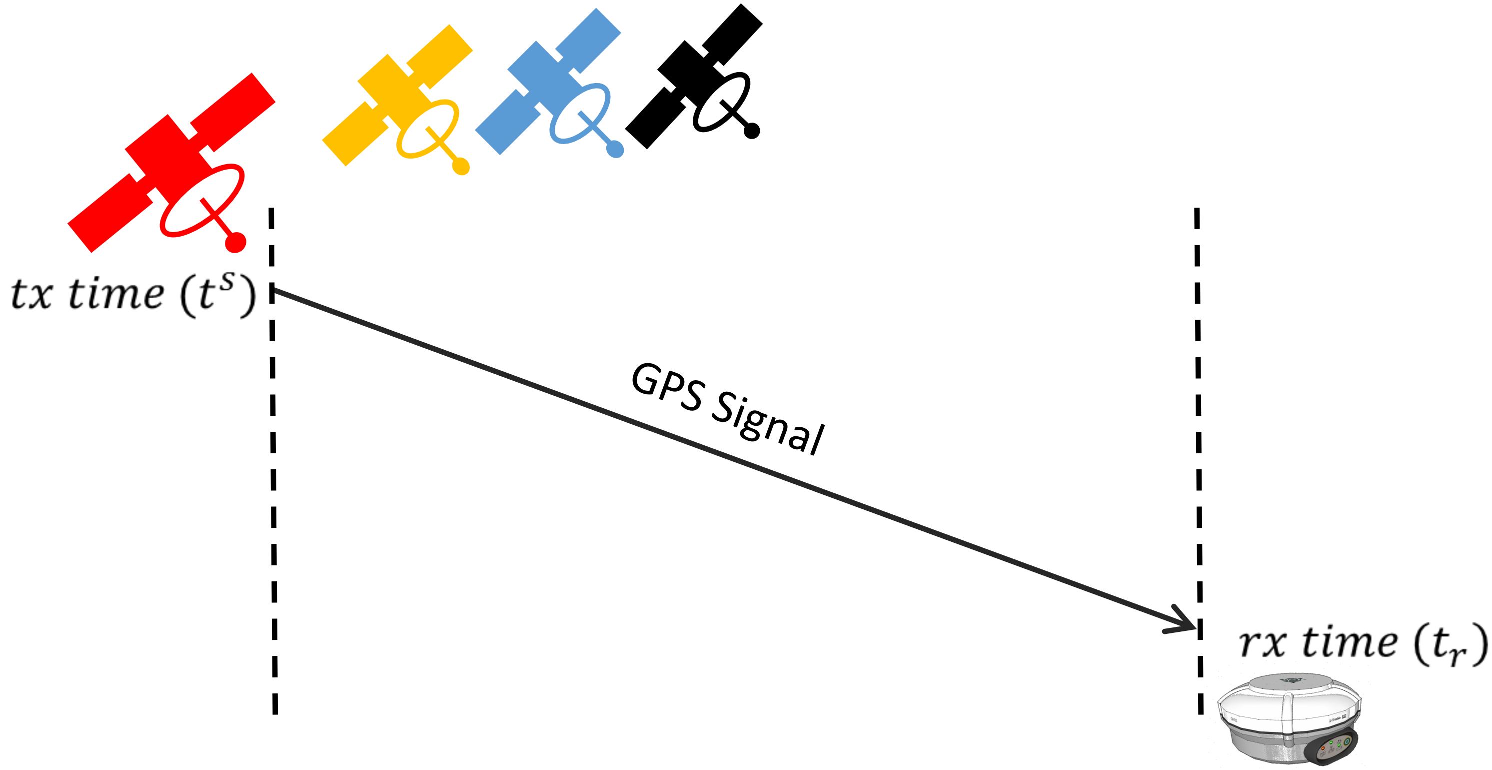
# Basic GPS Localization




$$Range(R) = (t_r - t^s) * c + \delta_{clk} * c$$

New unknown $\delta$ … use 4th satellite and estimate both location and $\delta$

# Basic GPS Localization

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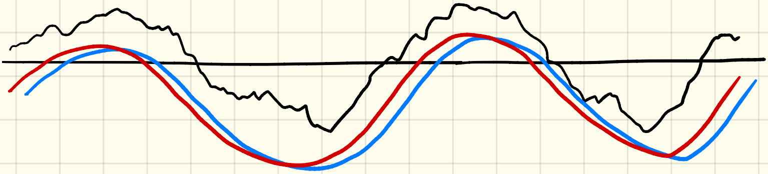
$$\begin{bmatrix} \text{Satellite Geometry Matrix} & \begin{matrix} c \\ c \\ c \\ c \end{matrix} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ \delta_{clk} \end{bmatrix} = \begin{bmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \end{bmatrix}$$

→ **1-3m error**

## ⊛ Estimating receive time $t_r$ at GPS hardware

↳ How to detect presence of a signal $s$ in received signal $Y$.



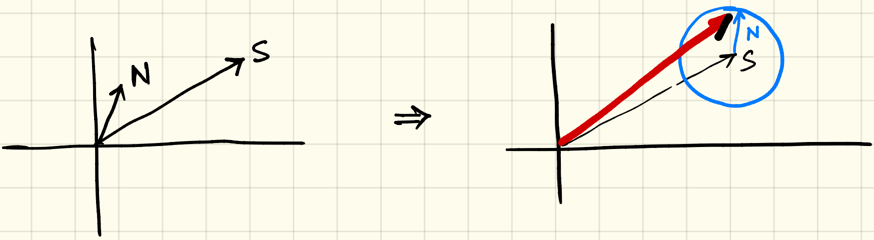
⊛ Given $[\, y_5 \; y_6 \; y_7 \; y_8 \; y_9 \; \ldots \,]$ Find $[\, s_1 \; s_2 \; s_3 \; s_4 \; s_5 \,]$

## ⊛ Correlation :

$$C = \qquad\qquad = \frac{1}{K}$$

But $y_i = s_i$ because of

Then, $C = \frac{1}{K} [$ —— $s$ —— $]$ $= \frac{1}{K}$




⊛ If , Then decoding possible.

↳ Thus, $S$ and $N$ need to be

i.e.,

↳ In practice, how will $K$ impact this $E[S.N]$ ?

↳ better is decoding.

→ Not enough

What if the signal changes slowly ... then s will also match well with

Thus, should

with signal s[n]

↳ called property.

↳ Ideally,

→ Moreover :

↳ signal Z, expected from should exhibit to S.

↳ Otherwise Z will and GPS receiver will detect the

→ Summary: necessary for satellite signals :

1. Uncorrelated to noise
2. Good auto-correlation
3. Weak cross-correlation

GPS uses that satisfy these properties.